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ABSTRACT

This six-chapter guide is designed to help Georgia teachers adopt or adapt various options into the local school's science curriculum. Major areas addressed in the chapters are: (1) secondary school curriculum development (focusing on performance objectives, sequencing the curriculum, evaluation, and scientific literacy); (2) teaching methods (including methods for teaching the scientifically talented and physically/mentally disabled students); (3) managing the science curriculum; (4) classroom and laboratory safety (providing information related to using chemicals, microorganisms, plants and animals, electricity, lasers, and rockets); (5) skills and strategies teachers should have for effective teaching; and (6) evaluation methods applied to student progress and programs of study. Course outlines for biology, chemistry, physics, and physical science, a list of essential science skills, and information on field trips are provided in appendices. The list of essential science skills is keyed to three grade levels (K-4, 5-8, and 9-12) and indicates at which grade level(s) a specific skill should be introduced, developed, or reinforced. (JN)

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Preface

The Georgia Board of Education mandates that all students receive instruction in science in grades K-8. State board policy also requires that each student graduating from any Georgia high school have at least two Carnegie credits in science to be eligible for graduation.

To help school systems plan for meeting these requirements, Georgia's science curriculum guide is being published in three parts. The first is a detailed, how-to-do-it guide for primary and elementary teachers in grades K-5. The second is a broader guide to science curriculum development for use by teachers in grades 5-8. This third in the series is offered for specialized science teachers in grades 9-12 as a general guide to secondary school science. Readers of this guide will find it nonprescriptive but full of options which can be adopted or adapted into local schools' science curricula.

The three documents have been written by Georgia's science teachers and educators and are based on needs expressed by science teachers at all levels. I am confident you will find these materials to be valuable planning guides in the development of local instructional programs.

Charles McDaniel
State Superintendent of Schools

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Introduction

During the decades of the 1950s and 1960s, the National Science Foundation, science educators and commercial publishing firms produced a remarkable array of instructional programs. These incorporated most of the features believed essential to sound practices in science education. Process skill development, inquiry strategies, attractive multimedia materials, alternative approaches to conceptual organization, prepackaged lab kits and other components were combined into impressive curriculum packages. BSCS, SCIS, S-APA, ISCS, ESS, PP and other acronyms became as commonplace in the vocabulary of modern science teachers as the more traditional and descriptive names.

By the mid 1970s science curriculum development had become an important field for commercial publishers. Series for K-6 science, intermediate science and all secondary disciplines were available from major publishers. Given this range of choices, one might ask, Why be concerned over curriculum content? Why not simply buy a program, train teachers and let the program dictate content? This may be common practice in many situations, but it is contrary to established principles of curriculum development. Science program goals for a Georgia school system should be extensions of the overall goals of the school system. This guide is intended to help achieve those goals.

Lucille Jordan
Associate Superintendent
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Chapter I

Secondary Curriculum Development

Educators involved in curriculum development should understand that goals for the local school systems are only a point of departure. Efforts to get somewhere in writing curriculum are easier when it is understood where we came from (LEA goals of education). Let's examine a few typical school system goals.

Students should

1. acquire to the fullest extent possible mastery of the basic skills in the use of numbers and words;
2. acquire the greatest possible understanding of themselves and appreciation of their worthiness;
3. acquire good health habits and an understanding of the conditions necessary for the maintenance of physical and emotional well-being;
4. understand and appreciate human achievement in the natural sciences, the social sciences, the humanities and the arts. (Barrow County Schools)

The list continues to develop as the community attempts to determine what values and skills will best serve the students and society. John I. Goodlad (1966) refers to the formulation of school goals as **societal-level** decision making and defines a school system goal as "a remote end for the guidance of educational activity. Statements . . . (that) imply both selection of values and commitment to education for their attainment."

Curriculum development bases content-related program goals on educational goals. For example

School system goal — Acquire to the fullest extent possible mastery of the basic skills in the use of numbers and words.

Program goals

1. To develop an understanding of common science terminology.
2. To use skills of reading, spelling and listening in science comprehension.
3. To use skills in math application to interpret science phenomena.

Goodlad defines program goals as the outcomes of **institutional-level** decision making. The development of program goals should be the responsibility of total faculty groups under the leadership of school administrators.

From program goals, decision making becomes **instructional-level** as broad content is honed by teachers into instructional objectives and teaching strategies based on the individual needs of learners. Obviously, with 20 or 30 broad program goals there will be hundreds of instructional objectives in the K-12 curriculum.

Common sense dictates the need to organize instructional objectives in some meaningful way. Organization involves **scope** and **sequence**. The scope of the K-12 science curriculum may be influenced by more than one factor (i.e., the development of science program goals from school system goals). In addition to teaching content, science education should teach skills aimed at helping students become lifelong learners and effective problem-solvers. Dean and Dean (1981) suggest five goals for science skills development.

1. **Motor Skills** — To develop within students the motor skills needed to conduct investigations of the natural, social and technological environments.
2. **Information Processing Skills** — To develop within students the information processing skills needed to gather and organize quantitative data into a manageable, usable knowledge framework of concrete and defined concepts and rules.
3. **Problem-solving and Decision-making Strategies** — To develop within students self-regulative problem attack strategies needed to use and modify acquired knowledge in the solution of the problems encountered in the academic and real-life environment.
4. **Affective Skills** — To develop within students a commitment to the concept that scientific knowledge is tentative, self-corrective and revisionary and continually shapes perceptions of the physical and social environment.
5. **Science Communication Skills** — To develop within students the skills needed to gather, evaluate, organize and use scientific knowledge generated and communicated by others and the skills to transmit both self-generated and acquired knowledge to others in a usable form.

Sequencing the objectives of a curriculum will probably be more difficult. Learning activities keyed to school system goals take place throughout the K-12 curriculum. A single learning event must be preceded and followed by many other individual learning events. Factors to be considered in planning the sequence of learning events are discussed later in this chapter.

Lists of instructional objectives are available for faculty curriculum development groups. The lists represent over 50 years of diligent work in this area. Federal, state and local education agencies, teacher training institutions and many commercial publishers are sources of expected science proficiencies for elementary, intermediate and secondary curriculum. There are several ways to develop the K-12 skills continuum. Figures I, II and III are three examples.

Key
I = Introduce
D = Develop
R = Reinforce

Figure I

Essential Skills for Georgia Schools

Topic		Concept/Skills	K-4	5-8	9-12
c. Matter		The learner will			
1. Description	a.	describe the surfaces by color, shape and texture.	I D	R	R
	b.	differentiate among solids, liquids, gases.	I	D	R
	c.	classify similar objects by particle size.	I	D	R
	d.	explain the difference between mixtures and solutions.	I		D
	e.	measure matter by both volume and mass.	I	D	
	f.	describe density as light or heavy.	I D		
	g.	predict ability of objects to float in water.	I	D	
	h.	define density as mass per unit volume.		I	D
	i.	explain changes in matter (form or phase) requiring energy exchange (input or output).		I	D
2. Structure	a.	explain structure of matter as array of atomic building blocks.		I	D
	b.	describe crystal structure by shape.	I	D	
	c.	explain crystals.		I D	D
	d.	classify matter according to theoretical structure, e.g., ionic or covalent (electrical attraction or electron sharing).			I D
	e.	describe the theoretical chemical atom as dense positive nucleus surrounded by negative electron cloud.			I D
	f.	differentiate between living and nonliving matter.	I	D	
3. Earth-Space Relationships	a.	describe earth as sphere in space, part of solar planetary system.	I	I D	
	b.	describe the solar system in the context of its relative galactic position and the theoretical relation among celestial objects.		I	
	c.	recognize sun as principal source of earth energy.	I	D	
	d.	describe climatic zones of earth (polar, temperate, tropic).	I	I D	D

Key
I = Introduce
D = Develop
R = Reinforce and Extend

Figure II

Skills Continuum*

Skills	**Grades** **K - 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
I. Biological Sciences												
A. Living World (environment)												
1. Ecology												
a. pollution		I		I			D					
b. conservation				I			I			D		
c. bio, geo, chemical cycles	I			I			D			R		
d. environmental interaction	I					D				R		
e. interdependence	I					D				R		
2. Primitive Life Forms												
a. viruses			I				D			R		
b. bacteria			I				D			R		
c. fungi			I		I		D			R		
3. Cells												
a. structure				I	I	I	D			R		
b. organelle function							I			D		
c. cellular reproduction							I			I,D		
B. Plants												
1. Classification	I											
2. Function												
a. photosynthesis					I	D				R		
b. reproduction	I				I		D			R		
c. nutrition and growth	I											
3. Plants and Man	I											
4. Heredity and Genetics	I											
C. Animals												
1. Classification		I	I	I	I	D	D			R		
2. Animals and Man	I											
3. Function												
a. movement	I	I	I	I	I	D				D		
b. respiration					I		D			R		
c. reproduction										I,D		
d. growth						I				D		
4. Heredity and Genetics	I									D		
5. Behavior							I					
D. Human Growth and Development												
1. Function												
a. digestion										D,R		
b. respiration				I						D,R		
c. reproduction				I						D,R		
d. nervous						I				D,R		
e. excretory				I						D		
f. circulatory						I	I			D,R		
g. skeleton/muscle				I						D,R		
h. endocrine						I	I			D		
i. epithelial				I						D,R		
2. Heredity and Population Genetics												
3. Behavior	I											
4. Social and Emotional Growth	I					D						

**Reprinted from Jefferson City K-12 Science Skills Continuum*

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Key
I = Introduce
D = Develop
R = Reinforce

Figure III

Science K-12*

		K-4	5-8	9-12
System Goal				
1.	Acquire to the fullest extent possible mastery of the basic skills in the use of words and numbers.			
Program Goals				
1.1.	To develop an understanding of common science terminology.			
Performance Objectives				
1.1.1.	Define basic words related to the concept of time, e.g., before, after, time, moving.	I	D	R
1.1.2.	Define basic words related to the concept of space; e.g., where, inside, outside, top, middle, bottom, near and far.	I	D	R
1.1.3	Use words that describe color, size, shape and symmetry.	I,D		R
1.1.4	Describe basic parts of a plant; e.g., leaf, flower, root, stem, seed.	I	D	R
1.1.5	Use words that describe primary science processes; e.g., measure, observe, etc.	I		
1.1.6	Use words that describe the integrated process skills; e.g., formulating hypotheses, operational definitions.	I	D	R
1.1.7	Use words that relate to temperature, e.g., warm, hot, cold, thermometer.	I		
1.1.8	Use terms describing simple physical changes in matter; e.g., melting, freezing.	I	D	R
1.1.9	Use words that relate to simple light phenomena; e.g., reflection, shadow, light, darkness.	I	D	R
1.1.10	Use words that describe magnetism.	I	D	R
1.1.11	Define words that describe basic animal functions; e.g., walking, swimming, flying, eating.	I,D		R

**Reprinted from Barrow County K-12 Science Continuum*

Sequencing the Science Curriculum

There are many factors to consider in sequencing the content and skill components of the curriculum. Levels of intellectual activity, attitudes, development of the child's thinking processes and development of instruction are all important.

Learning objectives should be sequenced in order of complexity. Bloom's (1956) taxonomy of educational objectives is the most used scheme for cognitive activity, and is suggested as a tool for sequencing instructional outcomes. While it is necessary in high school science to continue to develop knowledge and comprehension, curriculum planners are urged to seek balance by providing application, analysis, synthesis and evaluation objectives. A brief review of Bloom's taxonomic scheme using science as a context is presented in Figure IV.

Figure IV

Bloom's Taxonomic Scheme

Knowledge

The lowest level of cognitive activity, according to this widely accepted classification system, is the acquisition of knowledge by memorization. This includes memorization of knowledge at all levels—from simple terminology and facts to principles, generalizations and theories. In short, this activity consists of acquiring any information through the exercise of memory.

Comprehension

Demonstrations of various levels of comprehension rank just above memorization. Comprehension is manifested in such acts as paraphrasing or translating information into the student's own language, explaining and summarizing communications and determining the implications of given information.

Application

The application of information to problem situations ranks above comprehension in terms of complexity. Here the learner must select from a number of processes, skills or theories those that will help him or her to solve the problem. The learner must then apply these selections in some orderly sequence to realize his or her goal.

Analysis

Analysis generally involves the detailed examination of a statement or process according to some preconceived logical system. The learner may examine the parts of the statement or process individually, reorder them or substitute others to test the structure as a whole. A child would be operating at the analysis level, for instance, as he or she examined a model of an atom to see if it accounted for all he or she knew about atoms.

Synthesis

This level is especially important for science, for synthesis means putting parts together to form a new and unique whole. Children who are doing individual discovery and experimental activities are thought to be operating mainly at the synthesis level, as they derive hypotheses and devise methods for testing them.

Evaluation

This is the highest level of cognitive activity. It has become important that scientists form a humanistic system of values. Now that science may soon predetermine the characteristics of a race, and even create life itself, the scientist is faced with awesome decisions. (Esler and Esler, 1981)

Skills and content become important to the design of sequences for future learning. Sequential curriculum planning must be based, in part, on ascending cognitive development.

There is evidence that while the rate of technological progress increases in our society, science literacy is declining. Science literacy involves both knowledge and attitude. It follows that the K-12 science curriculum would be strengthened by attending to the attitudes of students. A taxonomy is helpful in identifying and sequencing student behaviors. The following affective taxonomy, Figure V, was developed by Krathwohl, Bloom and Musia (1964).

Science curriculum planners should also weigh sequencing decisions against an acceptable theory of intellectual development. Many modern science programs have been developed around Jean Piaget's (1958) theory of intellectual development. The difficulty in sequencing the instruction for a high school science program lies in the disparity in intellectual capabilities among high school students. According to Piaget, children enter a formal operations stage around age 11. The child should then be capable of performing logical operations mentally without relying upon the manipulation of concrete objects. Many science teachers have found, however, that a significant number of high school students must rely on the physical manipulation of concrete objects in seeking solutions to problems. This is not meant to imply that these students are **either** concrete operational **or** formal operational. The transition from one stage (concrete) to a more advanced stage (formal) is gradual and progresses across many areas of development. The implication for sequencing the science curriculum lies in efforts that assure manipulative experiences for students while providing learning opportunities that foster formal reasoning ability in the more advanced student.

There is little research supporting any particular conceptual organization of knowledge for high school science. From the five goals of science teaching presented earlier (Dean and Dean, 1981), it is obvious that science content is an important vehicle for skills development. What is not as obvious, however, is a systematic approach to conceptual organization. The Georgia Department of Education uses the following outline for organization.

A. Problem Solving (skill)

B. Process of Science (skill)

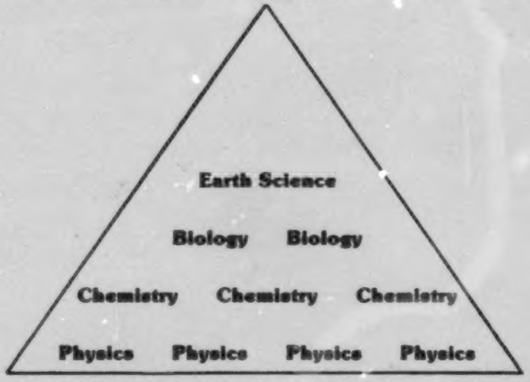
C. Matter (content)

D. Energy (content)

E. Interaction (content and skill)

Some authorities suggest that all science subject matter is either life science or physical science. Others regard this categorization as simplistic.

Georgia high schools generally adhere to the time-tested science curriculum of biology, chemistry and physics, in that order. DeVito (1979) notes, however, that physics has long borne the mantle of pure science and is the primary root of science. DeVito uses the following diagram to depict the structure of science.


Earth Science
Biology Biology
Chemistry Chemistry Chemistry
Physics Physics Physics Physics

It would appear that while this structure is logically sound, it is not parallel with the ability and interests of students at various grade levels. The lack of parallelism between the structure of science and the nature of the learner has resulted in our current practice of biology first for most, chemistry next for some and physics last for a few.

The American Association for the Advancement of Science (AAAS) has provided a widely accepted system to put the skills for doing science in categories. These skills are divided into two groups, the **primary** processes and the **integrated** processes. The primary process skills are described as follows:

Figure V

Taxonomy

Affective Domain	Examples of Student Behavior
Receiving (Level 1)	The student will — listen by turning to the correct page. — observe by pointing to the event. — give attention by sitting up straight. — be aware of the assignment by doing it.
Responding (Level 2)	— answer a question. — perform a task. — turn in work. — volunteer for a job.
Valuing (Level 3)	— follow the safety rules. — exhibit acceptable behavior. — initiate a task. — complete a job on time.
Organization (Level 4)	— resolve conflicting values. — change an opinion. — alter a belief. — adhere to a position. — defer making a judgement.
Characterization by a Value or Value Complex (Level 5)	— behave in a predictable manner in a laboratory situation. — voluntarily take a summer science course. — have identifiable personality characteristics in harmony with the tenets of a scientific attitude.

Primary Process Skills

Skill	Description
Observing	Using all the senses to identify and name the properties of objects and events.
Classifying	Putting objects into categories according to a predetermined set of properties.
Measuring	Developing appropriate units of measurement for length, area, volume, time, weight, etc.
Communicating	Compiling information in graphic or pictorial form. Describing objects and events in detail.
Inferring	Suggesting more about a set of conditions than is observed. Differentiating between observations and inferences, changing inferences to accommodate new information.
Predicting	From a set of events, predicting a future event. Using graphs to interpolate and extrapolate guesses.
Recognizing space-time relations	Describing the position of an object with reference to other objects or to time. Describing changes in the shape and position of an object over a period of time.
Recognizing number relations	Finding the quantitative relationships among data. Using the number line to perform arithmetic operations.

The integrated processes are formulating a hypotheses, making operational definitions, controlling and manipulating variables, experimenting and interpreting data. The integrated processes are actually combinations of the primary processes. Given an effective K-8 science program, secondary students should be capable of

(a) gathering and processing information,

(b) using integrated process skills,

(c) receiving and transmitting science information,

(d) formulating and using deductive-normative explanations and

(e) analyzing systems and formulating simple mathematical models.

The challenge of the 9-12 science curriculum is to provide stimulating and meaningful opportunities for using these capabilities in solving problems. Sequencing opportunities for the application of process skills at the secondary level is not a consideration if all students have the capabilities listed above. In the absence of previous opportunities for skill development and application, the skill component of the curriculum should reflect instruction aimed at the sequential development and application of integrated process skills.

Many science programs are based on a spiral approach for curriculum design. The spiral curriculum, introduced by Jerome Bruner (1960), proposes that content be systematically and periodically reintroduced. Each reintroduction should present a topic on a more complex level. This approach also serves another purpose. By reviewing previously learned material, retention of subject matter and transfer of learning are likely to improve. Certainly a spiral approach to curriculum development is compatible with Bloom's ascending taxonomy of cognitive objectives and Piaget's sequential stages of intellectual development. The success of the spiral curriculum at the secondary level will depend largely on the continuous sequential presentation of key science concepts in the K-8 curriculum.

Minimum Science for Science Literacy

Before determining the minimum amount of instruction to assure science literacy, a tougher question must be faced. What **is** science literacy? A review of the literature reveals no universal definition, but does reveal some shared ideas.

One definition for a scientifically literate citizen is one who can read and comprehend scientific literature as it might appear in the popular press. This definition, however, is perilous. A visit to the local newsstand will show what is being sold by the popular press as science. While there are some responsible publications, sensationalism seems to be the order of the day. The occult, astrology, UFOs and other pseudoscience topics seem to have captured the attention of the public.

The uncritical belief of the 1950s and 1960s in the power of science and technology to alleviate human problems has given way to the realities of the 1970s and 1980s. These later decades brought the proliferation of strategic weapons, the aftermath of a disastrous war, economic and aesthetic losses associated with diminishing natural resources, increasing environmental degradation, widescale famine and controversies related to genetic engineering.

Humans have never confronted issues so crucial to survival. It is not difficult to understand public disenchantment with science and technology given these conditions, but ironically there are probably no alternative solutions ruling out the use of science and technology. How do we reeducate people to recognize that science is a double-edged sword, but still has the potential to cut the bonds of disease, famine, pollution and other global ills?

Rusch (1979) calls for a science curriculum that no longer focuses on scientific inquiry in a pedantic and authoritarian manner. He also calls for an end to the 1960s focus of science education on production of more qualified scientists. Few students pursue any specific discipline beyond the 12th grade. If one accepts a distinction between interpretative and applicative knowledge, the science curriculum most likely to foster science literacy emphasizes interpretative knowledge. Interpretative knowledge would allow people to interpret new problem situations in the light of their existing knowledge. Scientific knowledge, however, should be integrated throughout the entire curriculum. This does not imply that science should become a faceless discipline taught from the context of other disciplines. The point is not to isolate science from all other knowledge and vice-versa. Science instruction should be part of a total curriculum that reflects real life. Science can provide the context for intellectual development while offering well-developed mechanisms for students to perceive and comprehend the world around them. People who cannot understand events and lack problem-solving ability are likely to be less independent and unable to control their own lives.

Pella (1975) also believes that we must depart from the practice of teaching science to produce "big scientists and little scientists, rather than literate citizens." Like Rusch, Pella suggests that scientific literacy as an educational aim cannot exist as a separate, single entity, but must be a component of a general literacy involving all academic disciplines. Literacy in science is an ability to perceive and comprehend human and natural phenomena, but it should not represent the only interpretation. Pella offers four main functions of science in general literacy.

1. The knowledge formulated as empirical and theoretical concepts, empirical laws, theoretical laws and protocols of development may be filed as a library to which one may point as existing (i.e., knowledge for the sake of knowledge).

This library of science can now

2. function in explaining natural objects and phenomena;
3. function in predicting natural structures and phenomena;
4. be applied technologically.

Finally Pella offers 15 characteristics of a scientifically literate citizen.

A literate citizen should be

1. able to communicate with other citizens of the world knowledge and ideas about natural objects and phenomena.
2. able to communicate with other citizens of the world about the use or control of natural objects and forces.
3. able to use empirical concepts and laws in his or her constant adjustment to the environment.
4. able to explain events in the environment in a rational manner.
5. able to predict events in the environment in a rational manner.
6. able to read accounts of developments by the scientific community.
7. aware of how empirical concepts and laws come into being.
8. aware of the difference between theoretical and empirical concepts and laws.
9. able to use theoretical laws in unifying empirical laws.
10. aware of how theoretical concepts and laws come into being.

11. aware that knowledge developed in the scientific community is probable rather than absolute.
12. aware that theoretical and empirical laws may be descriptive, comparative or quantitative.
13. able to translate experience of the natural world into knowledge.
14. aware of the scientifically accepted regulatory principles employed in the generation and application of empirical and theoretical knowledge.
15. aware that science is concerned with the empirical universe.

The science curriculum that produces such citizens requires years of careful planning and development. It is unlikely that, in the absence of a sound K-8 science curriculum, most secondary students will achieve science literacy. It would be difficult to depart from the time-tested science curriculum in hopes of devising new arrangements that would assure science literacy. The development of a scientifically literate citizenry should start in kindergarten rather than the ninth grade. The basic processes for K-12 curriculum planning and development are presented in this chapter and may be used to guide that development.

Dimensions of Scientific Literacy

Science represents a comprehensive view of the world and dependence upon scientific knowledge increases as technology advances. Science contributes to the general welfare of humanity and has had a significant impact upon the human condition.

Scientific literacy, then, is the goal of general science education. Yet seldom is the term *scientific literacy* defined. Dr. Victor Showalter of the Federation of Unified Science sees seven dimensions in scientific literacy and has identified factors within each to give the term meaning.

1. Understanding that the nature of science is all of the following.

   Tentative
   Replicable
   Humanistic
   Historic
   Unique
   Holistic
   Public
   Empirical

2. Applying scientific concepts, principles and laws including the following.

   Cause-effect
   Energy-matter
   Time-space
   Change
   Evolution
   Interaction
   Perception
   Symmetry
   Equilibrium
   System

3. Using the following scientific processes in solving problems and making decisions.

   Classifying
   Communicating
   Controlling variables
   Defining operationally
   Interpreting data
   Measuring
   Using numbers
   Using space/time relationships
   Designing experiments
   Formulating models
   Hypothesizing
   Inferring
   Observing
   Predicting
   Questioning

4. Interacting in constant ways with the following values underlying science

   Longing to know and understand
   Questioning of all things
   Search for data and its meaning
   Demand for verification
   Respect for logic
   Consideration of premises
   Consideration of consequences

5. Appreciating the interaction of science, technology and society.

   Recognizing the distinction between, the overlap of and the dependence upon science and technology

   Scientific thought and knowledge is objective but can be used to support different positions in response to specific problems

   Impact of scientific and technological developments upon the individual's life

Public understanding gap

Social influence on technology

6. Internalizing an interest and appreciation for science and the universe.

   Having an interest in learning Participating in science

   Preferring scientific explanations

   Considering science as a vocation or hobby.

7. Functionally manipulating scientific tools and instruments including the following.

   Timing devices
   Camera
   Meter stick
   Balance
   Tape recorder
   Graduated cylinder
   Thermometer

Georgia educators have a unique opportunity to use Georgia Board of Education Policy IHF, Graduation Requirements, as a springboard into innovative and visionary curriculum development or revision. There are virtually no competencies where science instruction would be inappropriate or ineffective.

The **learner** as defined by Policy IHF is expected to master basic skills in reading, writing, mathematics, speaking, listening and problem solving. A well-integrated secondary science curriculum will expedite mastery of all five basic skills and move toward Pella's general literacy of which science literacy is a part.

The **individual, citizen, producer** and **consumer** are deprived when schools fail to integrate science and technology. Consider this definition of the role of secondary schools in Policy IHF.

> *"The state board (of Education) defines as a major role of secondary schools the responsibility for providing the youth of Georgia with opportunities to acquire and to apply basic skills necessary for contemporary adult life. Such skills are defined as those skills which enable one to address effectively and efficiently the decisions and opportunities presented in a technological, urban, free society."*

There can be little doubt that this would be impossible without a sound science curriculum.

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Chapter II

The Science Teaching Process

Integration of Instructional Methodology

The key to integrating instructional methodology in science is identifying content that lends itself to multiple approaches and is conceptually complex. Thus it can be considered from different perspectives and on several levels simultaneously to allow for student differences in interest, learning style and ability.

Integrated methodology requires integrated content. As an example, students studying physical science are asked how a self-sustaining space colony for 100,000 people can be designed taking into consideration social, psychological, economic, physical and biological factors. The assignment is interdisciplinary and purposely open to varied interpretations. Any of the instructional methods to be discussed would yield significant results.

Similar problems abound in all areas of science. In general, such problems are broadly suggested by scientists and scholars, but the questions lead to practical science. In biology many problems can be viewed from the perspective of the unifying theory of organic evolution. In chemistry the concept of entropy cuts across a broad range of topics, and in physics the rapidly changing study of elementary particles suggests connections that arouse students' intellectual curiosity and stimulate their creativity. Finally, the study of the history and philosophy of science lends itself to a multifaceted instructional approach.

Before students can identify valid and significant scientific problems, they must be introduced to a body of scientific knowledge. They must be taught content through some combination of teacher-directed activities (lecture, discussion, films) and reading. Recalling and comprehending facts are necessary to deal intelligently with new situations. In addition to content background, students must acquire research skills. Both of these can be taught early in the science curriculum and later in a more complicated form — the spiral curriculum. Emphasis on process (experimentation, prediction, control) should continue from the elementary into the secondary school level, but with increasing integration with high level content.

Problems in science are solved through **experimental research.** Therefore research, both experimental and descriptive, belongs in the science curriculum. Students should be expected to conduct descriptive studies of significant problems and to design and implement experimental research projects for class credit (and perhaps for science fairs as well). A library research paper requires skills such as selecting a problem with some scientific significance; locating up-to-date references; abstracting key concepts from science magazines, articles and books; and writing a report using an accepted scientific style. These research skills can be taught through individual, group or class activities. The paper is the end product, but the means are important.

An experimental research project requires all of the skills outlined above as well as knowledge of experimental design, prediction, acquiring or building apparatus and statistical analysis. A student who produces a truly experimental project will be doing exactly what practicing scientists do. Some independent or class study of statistics is an integral part of developing experiments and is useful for the interpretation of experimental research in various publications. One of the hardest aspects of project conception and implementation is designing true experiments—hypothesis, experimental versus control group, dependent and independent variables, and deciding whether to accept or reject the hypothesis. Here is an experimental topic consistent with the larger space colony question posed earlier. What are the effects of overcrowding to mealworms? This is a problem in population biology that might lend itself to a predictive computer model.

Laboratory experiences should provide students with increasingly real experimental situations. Activities should provide enough information and technique to carry out the experiment, but the results should not be known in advance. Laboratories should be open-ended. A laboratory related to the space colony problem involves setting up a closed oxygen-carbon dioxide system using plants and animals. Students should compare experimental results during structured sessions in which validity, reliability, technique and data reporting are discussed. Students may fail in an experimental set up, but they should recoup some value in the form of improved technique and control. The significance of negative results should be explained.

The **use of the computer** in science classes is becoming increasingly feasible with the advent of inexpensive hardware and software. Students can profit enormously from the computer's capacity for simulation and model manipulation. Computer-assisted instruction is a powerful tool for individualizing the science class, but the potential for student produced programming is limited because of the high entry skills requirement. This is not to say that computers cannot be put to use for analyzing experimental results, however, because extremely flexible statistics programs are readily available in basic computer language.

Independent study may be made available to some science students. It is an approach in which research and experimentation can be conducted with minimal teacher intervention. However, student motivation, preparation, maturity and past learning are factors that will affect the success of an independent study program. Motivation is the most critical factor, but school and community resources can greatly enhance or hamper an independent study. Independent study is best integrated with the whole science program by giving elective science credit to students involved in independent work. A student should have a specific idea of what she or he wishes to study and accomplish and should be assigned to a faculty member whose background and personality are appropriate.

Although the initial phase of an independent study may be exploratory, specific objectives should be met and specific products completed. These objectives and products can be agreed upon using a contract against which a student's progress may be measured. The student should be involved in the evaluation. Independent study on a short-term, limited basis can be a component of any class. The appropriateness of independent study for individual students is assessed by the teacher.

Field studies involving individual students or groups provide immediate hands-on experience. Most scientific disciplines can be approached using this method—animal behavior in biology, energy flow in an old field in ecology, litter control in psychology, solar flare frequency in astronomy, and passive solar energy in physics. Field studies are highly motivating as well as significant in applied science.

Small-group work is an important part of scientific training since most scientists do not work alone. As groups prepare for presentations, they are required to select a leader, to identify specific aspects of a problem, to delegate responsibility, to insure the completion of tasks and to integrate disparate views and conflicting information. Groups may also be required to develop and present a coherent program.

Two areas in which small group work is appropriate are simulation and debate. Debates provide an opportunity for students to explore the ethical ambiguity of some scientific research. They also involve discussion of science in the larger framework of society. Simulations involving role-playing are especially valuable in the behavioral sciences. Simulations promote affective involvement.

It is always possible **to bring to the classroom individuals** who have made contributions to science. This can be done via videotape, but is a stronger teaching tool when the scientist is present in person. Another method of involving local scientists is in recruiting them as part of a mentor network, that is, as resource persons for particular students with intense interests and high motivation. Students who observe and work with practicing scientists invariably experience an amplification of their own interest and commitment to pursuing science as a career. The mentor network also cements school-community relationships.

A flexible science program is individualized within given classes, but its greatest flexibility should be as a whole program. Not only is curriculum carefully integrated, but students and teachers are also given options in their selection of appropriate problems and methods of attack. Far-reaching, broad spectrum problems lend themselves to variable approaches. The classroom and the laboratory are often one and the same, but space should be set aside for independent work (study carrels). Provision should be made for students to work in small groups at tables; and materials for student productions should be available. The degree of teacher direction may decrease through time, but the teacher's role is flexible.

Teaching Scientifically Talented

Consensus about a definition for the scientifically talented is difficult to achieve. Professional educators and practicing scientists disagree about what constitutes scientific talent. The former address such factors as past learning, potential and aptitude. The latter stress more operational criteria such as the ability to perform or conduct scientific research. Therefore, a scientifically talented student may be viewed as an individual whose potential as a high-level solver of scientific problems qualifies her or him for some special treatment which enhances abilities and maximizes achievement. Inherent in this is the assumption of superior verbal and mathematical ability.

Classroom considerations for the scientifically talented are complex. Should the student learn the greatest amount of scientific knowledge in the shortest period of time, or should the student train for eventual performance of scientific research? No single approach is adequate for teaching the scientifically talented.

Essentially three avenues are open to the teacher of the scientifically talented. One accelerates the curriculum to provide more content per unit of time; another develops enrichment activities to lift the student beyond the day-to-day progress of a regular science class, and the third rethinks the science curriculum to provide a broader, more integrated, more powerful model of what science is and does. Clearly, these routes are related. None of the routes alone is sufficient to bring the scientifically talented student to the realization of her or his potential. Such students are capable of learning science fact both rapidly and thoroughly, that is, with understanding. Equally, they respond willingly and with alacrity to enrichment of the science curriculum. It is in rethinking the curriculum, however, that the teacher can provide the powerful, unifying picture in science—a mixture of philosophy of science, science progress and science fact.

If the science teacher is to take advantage of and further develop the high-level cognitive abilities of the best students, content must be presented as highly integrated and interdependent. Students should be asked to derive key concepts and connections wherever possible, but, failing in this, they can profit from the teacher's providing them with these high-level connections. Content must include the methodology of model formation as well as those powerful models of the past upon which science is constructed. Techniques for problem solving are an important component of the science curriculum.

The facts of science provide students with the material upon which to use their abilities of synthesis and analysis, and presentation of factual material forms the first part of any science course. This content should be up-to-date and presented in a rigorous rather than over-simplified manner. The scientifically talented student has the capacity for grasping complex phenomena and concepts such as statistical probability and cybernetics. As early as possible, students should be exposed to professional scientific literature.

Science, at its highest conceptual levels, is interdisciplinary. It is, therefore, important for students to be made aware of interrelations among science and other disciplines. The teacher may ask where cytology leaves off and biochemistry begins and how technology affects progress in both. Hybrid or blended sciences such as astrophysics and sociobiology set up problems of ambiguity, the resolutions of which stretch students' minds much farther than a unitary or spiral presentation. Discussion of social and moral implications of scientific research involves the affective domain and taxes the student's ability to deal with uncertainty. Science curricula must be integrated with a sound mathematics program in which students learn not only the how of mathematics but also the why.

Research methodology is critical for the scientifically talented. It is important for students to differentiate between experimental and descriptive research and to practice significant problems in both realms. Methods of locating references become a part of the curriculum. Students read widely within an area of interest; they select a problem which can be solved; they narrow the focus of the problem; they locate and abstract significant research; and they set about solving the problem. Skill in these initial facets of research can be developed through consistent, guided practice and through insistence on rigor and honesty. Furthermore, students should learn how to design an experiment; how to express and analyze data statistically (chi-square and t-tests of fit and significance) and how to report results in a formal paper.

Laboratory activities provide hands-on exposure to the materials and techniques employed by scientists. They introduce or reinforce key concepts, and they develop scientific procedures such as hypothesis formation and testing and analyzing results. All of these are important and should be considered in developing the laboratory component of any science course. Laboratory activities contribute to skills development and to learning. Good laboratory activities produce products with a significant theoretical basis. Since they are both structured and open-ended, they approximate real scientific research. The development of useful laboratories is one of the most challenging aspects of science teaching. Teachers must avoid a cookbook approach without sacrificing structure. They should carefully consider the benefits of time spent in laboratory and activities. Is one week, for example, spent on frog dissection acceptable during the course of an otherwise largely theoretical biology class?

History and philosophy of science also show the interrelatedness of disciplines in science. Students learn the roles of hard work, perseverance and serendipity in science. The inseparability of science, scientist and society is stressed to show how science advances. The evolution from scientist as generalist to scientist as specialist is a consequence of the growth of scientific knowledge. This can be taught within the framework of key personalities, although it should go beyond mere biography. What formative experiences did Pasteur have? What do Copernicus, Newton and Einstein have in common? Philosophy of science raises fundamental questions about the nature of scientific assumptions. Discussion of philosophy cuts to the heart of the process of change in science—is it evolutionary or revolutionary? To what extent is science embedded in the sociopolitics of a given period? How do scientists identify significant problems? What are the social and ethical implications of scientific research in, for example, nuclear physics or molecular genetics? In philosophy of science the historical perspective is reinforced, but the student also sees the relativistic nature of science and its possible future. Frontiers in microbiology and particle physics excite students because of the immediacy of these areas. Philosophy of science, in general is an essential framing device for the science curriculum as a whole.

Teaching the scientifically talented must be as multifaceted as is the content. Teaching strategies include lectures, readings, discussions, laboratories, field trips, a field approach, use of mentors, use of students as elementary tutors and research projects. Lectures are the most parsimonious method of presenting content. Beneficial side-effects include the improvement of listening and note-taking skills. Readings usually begin with a textbook but should not be restricted to it. Supplementary readings provide depth and breadth. Discussion is valuable as a follow-up activity for laboratories and readings, but also for more formal activities such as group presentations. The teacher's role in discussion is Socratic and requires that questions be redirected with other questions. Laboratories promote the acquisition of real scientific skills and reinforce experimental research capabilities in students. Field trips should have specific objectives and should be preceded and followed by related content and activities. Ecology and vertebrate zoology may be enhanced by local, walking field trips, whereas a visit to a working electrical engineering laboratory may be of significance to the study of physics. The field approach uses descriptive research techniques and is adaptable to such subjects as planetary motion in astronomy, energy flow for a pond ecosystem in biology, water analysis in chemistry and erosion in geology. Many communities have practicing scientists and students with extraordinary interest and aptitude profit enormously from exposure to the actual practice of science. The teacher's role is to act as a go-between, to recruit scientists and to arrange meetings between mentor and student. Finally, secondary science students can serve as tutors (mentors) for elementary students. All that is required is a commitment on the part of the student and some flexibility within the secondary science program.

Activities for the scientifically talented include making models for specific concepts or problems, for example, computer models in population biology; simulating such things as stream flow and wave action; experiments, analyzing and reporting the results, writing the report using accepted scientific style; developing descriptive methodology in, for example, animal behavior or qualitative analysis in chemistry; abstracting scientific papers; and completing specific projects in areas of high interest.

Teaching the scientifically talented requires that the teacher the scientifically talented requires that dents who have well-developed interests and learning and, at the same time, maintaining rigor and integration while teaching new content. Of greatest importance is flexibility in both content and method. Science curriculum can be viewed as training for future scientists, but the broad social perspective should be maintained.

Science and the Handicapped Learner

Handicapped learners include the entire range of special education students, the mentally retarded, physically handicapped, visually impaired and hearing impaired as well as students with emotional or behavioral problems and those who are learning disabled.

In most school systems the current practice is to mainstream as many of these students as possible following the "least restrictive environment" directive of PL 94-142. As with any special youngster, it is important for the science teacher to approach these students with a positive attitude and high expectation. Provided the proper support and effective strategies, these young people can learn science, and many of them can pursue science-related careers.

A number of myths still exist about the capacity of handicapped students to perform. They continue to be perpetuated and they need debunking at the outset.

1. ***Special students need to know the basics, therefore, science should not be a high priority.***

   FALSE. Science is a basic. One only learns to read and write about the environment, but science is essential to explaining the environment. Handicapped students are often denied those hands-on science experiences which would help them in reading and communication.

2. ***Handicapped students are more vulnerable to injury than ordinary students.***

   FALSE. There are no statistics which show any correlation between physical injury and the handicapped.

3. ***Science is simply too hard for handicapped students.*** If their handicap is physical, they lack certain skills; if mental, they cannot understand concepts.

   FALSE again. There are thousands of handicapped people in the world who are scientists, doctors, marine biologists, chemists or geologists. All of them overcame barriers. Taught properly, handicapped students can enjoy more success in science than elsewhere in the curriculum because there are numerous multisensory activities.

4. ***Handicapped students in a regular class will hold others back.***

   FALSE. The teacher sets the pace for the science class and laboratory. Careful pairing of a handicapped student with a nonhandicapped student will enable the teacher to share some of the responsibility. Numerous services exist for helping these youngsters learn.

5. ***It requires special equipment and special training to teach science to handicapped children.***

   FALSE. Successful handicapped students report that the most important characteristic of their science teacher was the enthusiasm exhibited by the teacher willing to listen and help. In most schools resource people are available to work with regular classroom teachers to better meet the needs of special students, particularly the mentally retarded and the learning disabled.

Strategies for the Physically Handicapped Student

Barrier-free additions to school buildings have made it possible for orthopedically handicapped students and others with physical handicaps to attend regular classes. For a student confined to a wheelchair, laboratory materials might have to be made more accessible. Perhaps a low table could be added to the laboratory and a supportive student assigned as a lab partner to the handicapped student. For students with cerebral palsy and other conditions which make writing difficult, typewriters have been used successfully for note taking, writing lab reports and preparing term papers. An inexpensive cassette tape player could be used for taking notes. In classrooms where laboratory work is a large part of the course, computer simulation of the lab could be written for the more physically difficult laboratory exercises.

Many of these same strategies could be used for students who are visually handicapped or hearing impaired. The entire lesson could be put on a microcomputer for a hearing impaired youngster, if this equipment is available in the school district. Special education resource people should be able to help secure these services.

Visually impaired students in science could be helped by large print books which are available for the student with partial vision, by cassette tapes, raised-line drawings or simulated models.

The following is an example of how a unit on the circulatory system in biology could be taught to a visually impaired student.

1. Students can be given raised-line drawings of the heart and the pathway of blood flow through the body.
2. A cow heart can be dissected with students examining and identifying the various cavities and valves.
3. Tapes of normal human heart sounds can be played and compared with tapes of abnormal hearts.
4. Students can determine their own pulse rates and blood pressures using stethoscopes and sphygmomanometers.
5. Human heart models can be used for review.

A lesson in chemistry could be done using tapes, raised-line drawing to demonstrate bonding, small clay balls and toothpicks to represent atoms and electrons, molecular model kits. One instructor in California (Cooperman, 1980) uses taste to demonstrate diffusion and a tactual approach to osmosis and filtration.

Strategies for the Mentally or Emotionally Handicapped Student

The learning disabled (LD) and behavior disordered (BD).

Some students may be behavior disordered or emotionally handicapped and some may have one or more learning disabilities. In many cases an emotional component is present with the learning disability. When these youngsters cannot function in a mainstreamed class the only alternative may be to drop the class. In some systems science departments seem unwilling to deal with these students. A special education resource staff and a caring science department can combine efforts to give these students an opportunity to master required science courses in high school.

It should be pointed out that regular teachers must have some background in learning disorders and emotional handicaps. The special education course mandated by H.B. 601 now insures some knowledge in both areas. The learning disability is usually described as a perceptual disorder and is presumably caused by a neurological dysfunction which may result in a variety of learning problems. The primary disability may be an inability to perceive directions, poor figure-ground distinction (visual or sound), inability to understand verbal or written directions, poor eye-hand coordination, extreme distractibility, hyperactivity. In the high school science student, these are often manifested in reading, general comprehension, mathematics and science difficulties.

Behavior disorders may accompany learning disabilities. Because these students may have repeatedly failed in school, they may be hostile and refuse to complete work, or they may seek or demand attention. Students who are LD or BD may possess average or above average intelligence. They may be gifted — which adds to their frustration.

A science teacher who is successful with these students needs to have the ability to communicate with them emotionally as well as intellectually.

The science department at Alhambra High School in Phoenix, Arizona, (Slavin, 1979) set up a biology course specifically for LD and BD students. A number of specific problems were identified which science teachers are most likely to encounter with these students. They are as follows.

1. Learning disabled students are unable to handle an unstructured situation. They are not self-starters and cannot discipline themselves to accomplish a given amount of work each day.
2. LD students cannot set long-term goals. They are not capable of visualizing a unit of several weeks and working for a cumulative number of points. Even when a unit is broken down into weekly segments, some of these students still have difficulty pursuing a goal.
3. With conversation and activities going on around them, LD students are easily distracted. Consequently, they remain unable to attend to their own work. Their attention span is short, and they usually display varying degrees of either hyperactivity or lethargy.
4. LD students are unable to follow extended directions. This inability coupled with poor reading skills makes laboratory work difficult. Unless the instructions are read and followed with each student in a step-by-step fashion, or a teacher works with small groups of four or less, many students do not complete their labs.
5. LD students need individual attention. Most of them will work if a teacher or resource person is helping them, but they become frustrated or distracted and cease working without this attention.
6. The poor verbal ability of some LD students makes it difficult for them to communicate information they have learned. They cannot write necessary reports. Many are capable of an oral report, but this requires even more teacher time which, unfortunately, is not always available.
7. Many LD students have poor self-images. They do not see themselves as capable of doing correct work and thus become discouraged more easily than the average student. Possessing a low frustration tolerance, these students tend to give up or copy other student's work. LD students require constant reassurance with immediate rewards.
8. Many LD students have poor social skills and an inability to work cooperatively. Therefore, they reinforce each other in their acting-out behavior, outwardly manifesting their frustrations and hostilities.
9. Many LD students have difficulty making choices. When they must select one of a number of activities, they become confused and frequently make no choice at all.

Strategies which proved to be successful with LD and BD students include the following.

1. Carefully structured laboratories (A specific example designed for biology follows.)
2. Films, videotapes, filmstrips
3. Games, such as the "Teams, Games Tournaments" concept
4. Field trips

An example of biology laboratory for LD and BD students

Title — Flies and Bacteria

Problem — Do flies and other insects carry bacteria?

Materials

Two sterile petri plates with Soy Tryptic Agar
Few grains of sugar
Two flies or roaches, ants, etc. (alive)
Colony counter

Procedure

a. Open one petri plate, Plate I, just wide enough to put in one fly. Close top and allow fly to walk around on the surface of the agar.

b. Remove fly; put fly on second plate, Plate II, to which you have added a couple of grains of sugar. Try to get the fly to eat some of the sugar.

c. Remove fly, invert plates and put plates labelled with your name and period into the cabinet to incubate for 24 to 48 hours.

d. Remove plates from cabinet and place on the viewer.

e. Observe agar surface for bacteria colonies. Note number, color, size, etc.

Discussion

a. How many distinct colonies do you find? Why are these difficult to count?

b. How many different kinds of colonies do you have? Are you sure? Give a way to check.

c. Describe any differences between Plate I and Plate II.

d. Do you have any evidence that bacteria were on the fly's feet? If so, what?

e. Do you have any evidence that flies spread bacteria when feeding? If so, what?

f. How do you know the bacteria didn't enter the plates from the air?

Conclusion

Did this lab solve the problem "Do flies and other insects carry bacteria?"

Comment by summarizing what you have learned.

From *The Biology Teacher*, March, 1979.

The mentally retarded student and the slow student

The only difference between these categories may be a five or so point difference in an IQ score. One youngster may qualify for special education program and another with a slightly higher score would not. Both students may present a challenge to a science teacher.

Many of these problems also characterize some EMR (educable mentally retarded) and slow students. These students have also experienced failure and may be turned off to school in general. Science experiences are important for these students. Teachers working with these special youngsters soon learn that the most basic, the most concrete terms, must be used with them. Abstract concepts should be avoided.

Plant study or horticulture can lend itself well to teaching special students. Students need not understand the carbon transfer mechanism in photosynthesis to be able to plant and care for a garden. Visuals can be used to demonstrate plants dying because of lack of sun or water. Seeds can be studied and seed dispersal demonstrated by allowing students to see which seeds float in water, stick to clothes or fly in the air.

Special students can study insects and animals, rocks and other areas of science in which there are a number of possible activities.

All youngsters are interested in their bodies and special education students should be instructed in hygiene, proper nutrition, exercise, drug abuse and other health topics. For these students, health instruction may indeed involve survival skills as measured by the High School Improvement competencies.

It seems clear that with EMR and slow-achieving students, more of the same is not enough. Teachers must search for new strategies to involve these students in science if it is to be meaningful to their lives.

Although it is much easier to insist that handicapped youngsters do not belong in our classrooms—to think of them as deaf, blind, disturbed, crippled or retarded and thus take no responsibility for them—as science educators we cannot do that. Science may be the most important study in life. Science teachers must ensure that scientific knowledge is available to all students.

Science for the Handicapped Association (SHA), is an affiliate of the National Science Teachers Association. Membership in SHA is $2 per year and includes the newsletters and extensive ERIC bibliographies. If interested, write

Ben Thompson, Science
SSS200
University of Wisconsin — Eau Claire
Eau Claire, Wisconsin 54701
(715) 836-4164

Dr. Kenneth Ricker at the University of Georgia is a SHA officer and has authored a number of publications on teaching science to the handicapped.

Below are some resources listed in a recent SHA newsletter.

1. ***Science for the Handicapped - An Annotated Bibliography.*** ERIC, 1200 Chambers Road, Third Floor, Columbus, Ohio 43212.
2. Jefferson County Schools in Lakewood, Colorado, are developing "Parallel Science Materials", a project for mainstreaming LD, slow learners and other handicapped youngsters into the regular science program. Write Margaret Barkey, Jefferson County Public Schools, 809 Quail Street, Lakewood, Colorado, 80215 for details.
3. SAVI (Science Activities for the Visually Handicapped) is available through Ideal School Supply Company, 11000 S. Lavergne Avenue, Oak Lawn, Illinois 60453.

   These are modular programs and some can be used with orthopedically handicapped and LD youngsters as well as the visually handicapped.
4. ***Search for Solutions*** the film series sponsored by Phillips Petroleum Company, shows a number of present day handicapped scientists at work. For information on the free film, write

   Search for Solutions
   The JN Company
   P.O. Box 388
   Woodbury, New York 11797

Chapter III

Managing the Science Curriculum

In an age of constant technological and scientific growth and development, the science supervisor's or coordinator's job has become increasingly more difficult. Curriculum management and improvement require supervisors and teachers to be intelligent consumers of research. The amount of scientific and educational research and development under way is almost immeasurable. Managing the science curriculum is a difficult task of constantly adding and deleting information needed to produce scientifically literate students.

Programs change daily and the educational approaches introduced to teaching science seem endless. Many of the national curriculum programs encourage inquiry and a hands-on laboratory approach to teaching science while many traditional programs rely heavily on lecture. It can be disasterous to a science program if the teacher has been trained in one method and the science curriculum moves to the other. Science teachers need a good background in all methods of instruction.

Science needs to be presented as inquiry and investigation. The scientific method becomes activity oriented rather than fact oriented. The scientific method should teach an ordered process for getting a job done rather than a cookbook solution to be followed in all circumstances. Students develop alternate ways of looking at common things. If the science curriculum is to provide learners with a realistic view of science, it should provide opportunities and active support for comprehension and application of basic skills.

Science then can be many things to the learner. It can be a combination of applied inquiry skills and a predisposition to view different things from unusual prospectives. It is a generalized collection of behavior, understanding and attitude rather than a group of academic disciplines with scientific names.

Science needs to be revitalized in the school curriculum. Science in the elementary school is sometimes overlooked. This results in apathetic science students at the secondary level.

This publication is designed to help the science manager work with curriculum development and become aware of potential problems. Since the curriculum involves everything needed to provide for the education of students, the possibility for problems seems almost endless. This publication should serve as a source of information for solutions to problems and for development of new ideas.

Role of Science Curriculum Leaders

The role of the manager of the total science curriculum seems to go through a constant evaluation. The titles given to these positions change from supervisors to coordinators to evaluators or to managers almost yearly. The solution to the problem, however, does not lie with titles. Names are not as important as the question of organization and roles.

The power of the supervisor or coordinator as a force for curriculum change has steadily diminished. Forces outside the education system continue to leave the supervisor or coordinator as a curriculum expert on the sidelines. The reasons for this can be many, and the science coordinator may even encourage this exclusion.

Generally, the science supervisor or coordinator is preoccupied with teaching and stays away from curriculum development. This can be a matter of choice or due to inadequate preparation. When untrained to perform a function, a person generally does not see it as a role. Since most science supervisors or coordinators were teachers, their experiences lie in instruction and not in curriculum development.

Present preparation programs in curriculum are weak and inconsistent. In many institutions supervision is in the department of education administration, and the program is likely to stress teacher evaluation and quality control. Some accredited programs require only one course in curriculum development. When supervision is in a department of curriculum and instruction, curriculum planning, assisting teachers and in-service training are usually stressed.

Some educators believe those in supervision should not be involved with curriculum development but limit their energies to the improvement of classroom instruction. For our purpose, supervision and coordination will involve both curriculum development and improving teacher effectiveness. The role of the curriculum leader should be to translate theory into practice and to contribute to theory development.

Structuring the Secondary Science Curriculum

Many changes have occurred in education during the last few decades, some excellent, others questionable. The science curriculum seems to have been exposed to some questionable changes.

Where definite lines were once drawn for courses in pure science such as biology, chemistry, physics, there now is a trend toward more specialized high school courses. The quarter system introduced the idea of courses in human biology, vertebrate zoology, invertebrate zoology, genetics, organic chemistry, force and motion, mechanics and others. On the surface this seemed good. Teachers and students were usually concentrating on a specific topic area they both enjoyed. The problems surface with the realization that students complete their required science with a limited science background. They may know everything about astronomy and geology but virtually nothing about biology and oceanography.

Back to basics is often heard in education circles. If the educator is a little more positive in approach, he or she may express this idea as "forward with fundamentals." Whichever way it is stated, the meaning for science educators is clear. Students need to experience a good, solid general science program at the secondary level. One way of assuring that students are not graduated without a good science background is to have a well-written and well-organized curriculum guide that includes scope and sequence. If teachers are left to teach without a roadmap to follow, it is unlikely they will ever reach the goals set down.

With this in mind, the science administrator should begin to tackle the development of a meaningful science curriculum. The science curriculum should be determined by student needs. Information, ideas and opinions concerning student needs should be solicited from teachers, administrators, parents and the community. Curriculum development is often a haphazard process with decisions made by impulse or rule of thumb or by whatever may be in vogue at a particular time. A systematic needs assessment will help avoid this problem.

A survey instrument usually works best. A random population sample provides information from all parts of the community. The survey should be easy to read and have a simple method of replying to questions. A Leikert scale survey form can be used with space available for additional comments.

Student needs should be rated and objectives derived from them. These objectives should become part of either a long or short range plan. Some objectives may be reached in a year while others may require more time.

Whether plans are long or short range, they need to follow the systems overall mission and have strategies for action. Changes begun without a plan will be haphazard and doomed to failure. A written plan is essential to unified effort.

A strategy for changing the curriculum should be developed and all teachers, administrators and professionals in the system should know the changes. People react better to change if it is not a surprise. Finances should be considered along with the resources available to implement a new science program. There should be adequate in-service for all who will be teaching the new science curriculum. Any new program has a better chance of succeeding with well-trained teachers.

With any new program teachers should have initial training then periodic meetings to deal with problems. This procedure keeps teachers on the right track and makes it easier for them to ask important questions.

When writing a curriculum guide, a definite format should be included. The first and most obvious entry for a curriculum guide would be the **course name** and **computer number**. The name of a course should be self-explanatory. The course number should also have meaning. A good plan to follow would have the digits in a course number give some information about the course. For example, the first digit of a number would signify the science department while the second digit identifies the grade level. The third digit might indicate whether a course was remedial, basic, average or advanced, and the fourth digit might show the semester or quarter of a course. In 7102, seven would indicate the science department, the one a ninth grade course, zero the remedial level and two the second semester or quarter.

The next segment of the guide should be a **short course description.** This lets the reader know whether to read any farther. It also allows the teacher to describe the course briefly.

Course objectives should then be listed. All course objectives should be matched with performance indicators. A teacher should know exactly how a student is expected to perform after the course has been taught. All course objectives and performance indicators should be keyed to competency-based education objectives.

The curriculum guide should include a well-clarified scope and sequence. Often the terms **curriculum guide** and **scope and sequence** are confused. A scope and sequence lists the skills or objectives introduced, developed and reviewed at definite grade levels. A curriculum guide lists objectives and an outline for each course taught. The scope and sequence is like a large-scale map of a large area, while the curriculum guide acts as a small-scale map with more detail. An excellent reference to use when developing a science scope and sequence continuum is the ***Essential Skills For Georgia Schools***. The format can aid in developing a local continuum.

A curriculum guide should organize learning experiences. Students should have a good balance of different learning experiences within the classroom. What they learn at one grade level should be built upon at the next. Teaching methods should be varied and learning experiences outside the classroom should be encouraged. If the lecture is the only procedure ever used, adequate learning cannot be taking place. Laboratory experiences, field trips, guest speakers and audiovisual materials all need to be listed as additional activities and resources in a course guide. Many teachers are too busy to plan for these experiences, and a curriculum guide can be their tool.

Every curriculum guide needs to be evaluated. The best way to assure meaningful evaluation is to build in an evaluation system. Teachers should annotate the guide, listing opinions, problems or successes with each part. It is important that the science supervisors or coordinators be visible and available when the guides are first being used. They should discuss the guide periodically with teachers.

Corrective Feedback to Foster Creative Teaching

Good teachers are not born but molded by teaching in a good educational system. Many teachers say they learned more during their first year of teaching than they learned in four years of college. Classroom experience is necessary to develop a good teacher. Good teachers never stop learning. Thus staff development is essential in every school system. Educators need to understand the programs they are expected to teach.

This is especially important for science teachers because the subject matter changes almost daily. The science supervisor or coordinator should provide meaningful staff development programs.

Science teachers should be familiar with national curriculum projects such as BSCS, Chem Study, CBA and PSSC. These and other science curricula emphasize inquiry as a learning objective. Teaching inquiry processes demands the teaching of content inseparable from process. Many science teachers find this difficult since they are not familiar with the inquiry processes. They need to see inquiry as directed toward increased understanding and application. This can sometimes puzzle the pure scientist.

These national curriculum projects offer problems for students to solve to increase understanding and application. Traditional teachers find this extremely difficult. There is no order of steps or classical scientific method to follow. Many times these programs fail because teachers were not prepared to teach them.

Any change, whether it is a national curriculum project or not, is difficult to implement. A good communication system can help to smooth the way for change. People accept changes better if they have a part in planning them. If a change is designed to help teachers make sound curriculum decisions and meet teachers' needs, staff development is important.

Any staff development program should meet teacher needs. Becoming a good teacher is not an impossible task for most education college graduates, but sometimes help is needed. Staff development provides that help.

Staff development ideas should be developed and suggested to the teachers on a survey form. Use community resources to help implement staff development programs. If a local college is available, recruit professors as guest speakers or as resource persons. Community agencies such as the public health department, government agencies and laboratories, hospitals, the Red Cross, the American Cancer Society, the Georgia Lung Association and others help make the staff development classes more enjoyable and meaningful.

The Georgia Department of Education has made a great step forward with Beginning Teacher Assessment. This instrument helps the teacher become the best possible educator during the first three years of teaching. Many suggest that this instrument also be applied to veteran teachers. Many of our veteran teachers possibly could benefit from feedback to foster creative teaching.

The state teacher testing program can be beneficial also. Screening out incompetent teachers early is not only good for the students but helpful to the teachers themselves. A recent state poll revealed that many teachers would not choose education as a profession if they had it to do again. This feeling does not benefit students or teachers. Better screening procedures used now may prevent similar problems in the future.

Communication: Teacher Supervision Contact

Whether your system is located in a small, rural area or a heavily populated metropolis, a common problem is the lack of communication. Good communication is not only important to the proper execution of the science curriculum; it is essential to high teacher morale. No one likes to be the last to know.

With proper planning good communication is possible. First, all science teachers should have a copy of the curriculum guide. It is difficult to hold someone responsible for teaching material if the outline is not available to them. It also is impossible for teachers to provide meaningful feedback concerning the science curriculum if they have never seen it. This feedback is essential to the improvement of an existing science program.

Once all teachers have been exposed to the curriculum guide, a system of contacts must be established so information can be disseminated and feedback received. The curriculum coordinating council is one useful system.

The curriculum coordinating council usually consists of the science department heads of the secondary schools. These department heads meet monthly with the science coordinator or supervisor to discuss information concerning the science program. At least one week before the meeting, the department head gathers with the teachers in the department to discuss concerns. These concerns are written in the form of minutes and forwarded to the science coordinator or supervisor. Solutions to problems mentioned in the minutes can then be established before the curriculum coordinating council meets.

After the council meets, department heads should relate useful information to the principal and other department members. The minutes from each council meeting are forwarded to the Assistant Superintendent of Instruction. This formal procedure should succeed in keeping everyone informed and allow for teacher problems to be dealt with quickly.

A normal month might be organized in the following manner.

First week
Department heads meet with members of their department and submit minutes to the coordinator or supervisor.

Second week
Department heads meet with coordinator to gather information and deal with problems.

Third week
Coordinator submits minutes to Assistant Superintendent and department heads meet with principal to discuss new information.

This cycle of sharing information will help teachers and administrators stay better informed. People are more happy in a position if they have an understanding of what is happening.

Curriculum Mapping as Communication

Curriculum mapping is a systemized pattern of checking a teacher's progress through curriculum material during the school year. It helps the science coordinator or supervisor know how the curriculum material is being used, and it helps the teacher follow his or her own progress through the required material covered during each course.

Curriculum mapping can be formal or informal. Formal mapping involves detailed paperwork and definite reporting dates. Informal mapping requires the science supervisor or coordinator to visit and note what material is being covered. Subsequent visits should reveal how much material can be covered.

This information can be used for competency-based education development and provides information concerning the usefulness of the curriculum guide. For example, a guide written for a semester course that only contains materials for 12 weeks needs to be rewritten. The same would be true if there was too much material to be covered in a limited amount of time.

Curriculum mapping can also assure that competency-based education objectives are being met in all classes. Writing material in a curriculum guide does not assure that it will be used. Curriculum mapping insures that the guide is taught.

How to Identify Excellence in Science Teaching

The science supervisor or coordinator is responsible for assuring excellence in teaching. A good interviewing system helps the science manager to secure good teachers. All science applicants should be interviewed by the science supervisor or coordinator as well as the principal and personnel director.

The first requirement of a science applicant should be knowledge of the subject. The state testing requirement for beginning teachers is one effective tool, but a good interview will usually identify the exceptionally gifted teachers. Of course, the teacher who views her or his function as simply surveying large quantities of information will not be justly serving students or science. Science is more than content. It is a combination of content, process and values. A teacher gifted in content also must emphasize process and values or science is not represented accurately.

There are numerous teaching strategies used to move students from one learning level to the next. Of all methods, lecture is used most often and has the greatest number of disadvantages. The only advantage of lecture method is that it is a means of distributing a vast amount of knowledge. However, most students are not capable of assimilating this much information, and there is a definite lack of student feedback.

When this procedure is modified to the lecture-discussion technique, students have an opportunity to enter the process of inquiry. Class members participate actively and emphasis is placed on the manipulation of data and not simply the collection of data. Students become involved with deductive thought processes which more accurately represent science.

A third teaching strategy is the demonstration method. A demonstration is simply showing something to another person or group. The demonstration can be performed by the teacher or student. This generally gives students an opportunity to participate in group problem solving when the phenomena being tested is too expensive or dangerous for normal laboratory work. This strategy can result in only a few students becoming involved with the demonstration and even worse the teacher directing too much influence. Teacher problem solving takes place rather than student problem solving.

Another possible strategy would be the laboratory experience. This provides more concrete experiences and the students can manipulate objects. The student has the chance to discover the essence of science when designing and evaluating laboratory experiments. Since laboratory work is expensive and time consuming, it is not at all beneficial to the student if only detailed workbook directions are given. Laboratory work affords students an opportunity to discover and inquire.

Field trips probably rank second to lecture in the extent to which they are abused. Many field trips have only entertainment value. The student participating in a field trip should realize exactly what is expected. Every field trip should have pretrip and trip follow-up materials for teacher use.

Science projects and research reports are other strategies that a science teacher might use. Both of these emphasize individual effort which means student involvement determines success or failure. The teacher directs students through this opportunity for self-discipline. This method is especially good for gifted students to pursue in depth areas of particular interest. This strategy does not favor students who have not developed independent study skills.

The good teacher should incorporate all of these strategies into lessons. The content and students to be taught should be analyzed. The teacher then determines the best strategy to use. If students demonstrate expected behavior, the strategy chosen was correct.

If the students cannot demonstrate the expected behavior, the teacher evaluates the results and designs another strategy. This pattern of behavior and planning indicates an excellent science teacher.

Equipment to Support Curriculum: Managing and Maintaining It

Anyone who has ever been in a science classroom realizes there is a tremendous amount of equipment necessary to support the curriculum. It is extremely difficult to manage or maintain this equipment without a good inventory system.

Inventories can be manual or computerized. The advantages to a computerized inventory are obvious, but it is not always possible to computerize. Inventory forms should be concise and easy to use. If inventories become too detailed, they can become cumbersome. It is not necessary to know how many test tubes each classroom or school has, but it is important to know how many microscopes, balances, lab sinks, gas jets and other nonexpendable pieces of equipment are in the laboratory.

Compile a list of all materials which should be reported. Consider equipment that must be maintained first. It is imperative to have an accurate count of materials to set up maintenance contracts. The next items to consider are those replaced on a regular basis. This information is extremely useful for budget purposes.

Science equipment is expensive to purchase and replace. Good maintenance helps to prolong the shelf-life of more delicate equipment. If an up-to-date equipment inventory is available, service contracts can be written for repairing and cleaning microscopes, balances and other equipment which need periodic maintenance. Equipment should get preventive maintenance yearly. Using equipment without maintenance reduces the length of usefulness.

All laboratories should have lab sinks, gas jets and electrical outlets in good working order. These should be checked periodically by school maintenance personnel or by an outside agency. Again, preventive maintenance can keep these in good working condition. Teachers should train students in the proper and safe use of the lab.

Storing materials and equipment must be carefully planned. If materials are stored in a central area, then distribution and transfer of equipment and materials are an essential part of the science supervisor's job. Even if materials and equipment are purchased and stored by individual schools, a system of priority ordering should exist and be monitored by the science department chairperson. Include a priority ordering list for each course in the curriculum guide.

Priority ordering is a system in which each course has a list of materials necessary to its proper execution. No other materials should be purchased until all of the essentials are available. This serves several purposes. First, it makes the best possible use of the money available for purchasing, and second, it helps eliminate impulse buying. Often we purchase for a teacher and not for a course. The teacher may leave and the equipment is not used by the next educator. Equipment purchases should be in line with course objectives and not necessarily with teacher requests.

When equipment is ordered there are usually only two paths to follow. Either the purchasing department will put materials up for bid or follow a procedure of sole-source ordering. If the bid procedure is followed, quality control is a must. A low bid item is of no benefit if it falls apart in a year's time. There must be an acceptable balance between reasonable costs and quality materials. It is essential that the science coordinator or supervisor work closely with the purchasing agent. Review all bids to assure that specifications are followed and follow through by examining materials received.

The second kind of inventory is the chemical inventory. A chemical inventory enables monitoring materials in the schools which may become depleted, and it helps to keep the safety inventory of dated chemicals current. Without an accurately dated inventory, chemical shelf-life is unknown and disposing of out-of-date chemicals becomes a guessing game. This procedure is not only expensive but dangerous.

Preparing students for lab work is essential. Teaching basic lab techniques and first aid procedures will help students to react quickly in an emergency. The first day of any lab course should be devoted to reviewing safe lab procedures.

Chapter IV

Safety in Science Instruction

The **teacher** is directly responsible for students' safety and it is unlikely that a court would transfer the responsibility of a student injury from the teacher to the employer (board of education) or supervisor. Science teachers can avoid being held personally liable for accidents if **reasonable care** is exercised. This means the science teacher must foresee possible dangers. The following information is taken from the third issue of the ERIC/SMEAC information bulletin for 1980.

What must be done by a science teacher to demonstrate reasonable care for student safety?

As with many aspects of instruction, planning is important in establishing reasonable care. In planning teacher demonstrations or student experiments, examine each activity considering the educational merit versus hazard. Once hazards are identified, alert students to risks and make them aware of proper safety procedures.

Courts have ruled that simply posting instructions or rules is insufficient. To demonstrate reasonable care the teacher must remind students of general safety instructions and provide appropriate specific instructions before each activity. The teacher cannot rely on general instructions given earlier. During the activity, the teacher's responsibility is to provide adequate supervision including the selection and use of designated chemicals. A teacher who must leave the room for a chemical or item of equipment may be open to charges of negligence.

The concept of reasonable care also extends to activities such as field trips and independent student projects. In the case of field trips, a teacher should visit the site prior to the trip, determine possible hazards and forewarn students of hazards. General rules for safe conduct should be reviewed before the trip. Individual student projects, whether for a classroom project or a science fair, should be thoroughly checked for safety. When planning projects, question students about safety precautions taken in working on projects and any specific hazards that projects may pose. Any project which will be viewed by the public should be constructed so that observers are protected from possible accidents.

Many teachers ask students to run errands both on and off school property. These students possibly would be considered agents of the teacher and liability for any damage caused by the students or injury to the students would be assessed on the teacher. This practice should, therefore, be avoided.

What are some general safety procedures for the science laboratory?

Conduct a periodic classroom inspection to identify the location and condition of fire extinguishers, first aid kits, showers and eyewash. General good housekeeping should be maintained including the proper storage of materials and equipment.

Be aware of proper accident procedures, fire precautions and evacuation routes.

Be aware of federal, state and local regulations which relate to school safety.

Make spill packages available, have metal containers for the disposal of broken glass, and maintain a sand-filled container for the disposal of matches.

Be aware of the location of the main utility shutoff valves and switches for water, gas and electricity.

Maintain hazardous materials under lock and key at all times. Maintain only minimum amounts of chemicals in the classroom. Lock all laboratory and storage facilities when they are not under direct supervision.

Properly label and date all reagent bottles.

Guard against poisoning by providing adequate ventilation for volatile substances, by providing instruction on the avoidance of ingestion of chemicals or plants, by identifying dangerous plants and animals and by providing safeguards against radioactive contamination.

Provide shielding for the teacher and students for demonstrations involving the possible explosion or implosion of apparatus or the possibility of injury due to spattering.

Provide sufficient time for students to set up the equipment, perform the experiment and properly clean up and store the materials after use.

Set a good example when performing all demonstrations.

Instruct students concerning specific hazards and precautions at the beginning of each science activity.

Obtain certification in first aid from the American National Red Cross.

Establish group size appropriate for efficient performance of the exercise without confusion.

Instruct students never to eat or drink in the laboratory and never to use laboratory glassware as food or drink containers.

Require that chemical goggles be worn in any situation that is a potential source of splashes, spills or spattering (hazardous chemicals, hot liquids or solids, radioactive materials).

Instruct students never to perform any unauthorized experiment or to use unauthorized equipment or materials.

Caution students to exercise care in noting odors and never to taste, touch or smell substances without specific instructions from the teacher.

Do not permit students to touch laboratory equipment until instructed to do so.

Perform demonstrations or experiments before allowing students to do the activity. Identify hazards related to the procedures, equipment and materials.

Instruct students never to pipette chemical reagents by mouth.

Instruct students never to force glass tubing into a cork or stopper.

Instruct students to slant test tubes away from themselves when heating them and never to discard matches in the sink. Remind students of the low visibility of burner flames and have them exercise caution regarding long hair and loose clothing.

Have students keep materials other than lab manuals or notebooks away from the working area.

Instruct students that it is unsafe to touch the face, mouth eyes or other parts of the body after working with plants, animals or chemicals until they wash their hands thoroughly.

Provide adequate supervision of the laboratory at all times.

What are some specific safety procedures with regard to chemicals?

In addition to the safety procedures for each exercise or experiment, the safe use of chemicals involves four major areas. The teacher should be aware of proper storage procedures, proper disposal techniques, chemical toxicity and unstable or incompatible chemical combinations.

The proper storage of chemicals should provide security against unauthorized removal of the chemical, protect the environment by restricting chemical emissions and protect the reagents from fire. The room used for this storage should be well-ventilated, dry and protected from sunlight and localized heat such as hot water pipes. The room should always be kept locked when not in use.

Store liquid flammables in safety cans not larger than one gallon and place in a separate metal cabinet. This includes such items as gasoline, kerosene, methyl acetate, methyl alcohol, ethyl ketone, petroleum ether, propyl alcohol, pyridine, toluene, turpentine and xylene.

Oxidizer storage should also be in a separate cabinet which is lightfree and lockable. Chemicals stored here would include ammonium nitrate, potassium chlorate, potassium nitrate, potassium permanganate, sodium nitrate and metallic sulfates or permanganates.

Control storage (lockable) should be provided for the remainder of the chemicals. Metallic sodium or potassium must be stored under kerosene and containers of sodium, potassium, calcium or calcium carbide should not be stored above water solutions or containers of water. White phosphorous must be stored and cut under water and the water changed occasionally as it becomes acidic.

Special care should be exercised in the storage and use of ether. Ether reacts slowly with oxygen to form peroxides that are explosive. These unstable peroxides are less volatile than ether and have a tendency to concentrate. For maximum safety ether should be procured in quantities that will be used once opened.

In many school laboratories hoods are used for storing chemical reagents. Storage of volatiles or flammable materials in a hood necessitates that the hood operate continuously; most hoods are not designed to function in this manner. Hood storage often results in a corrosive atmosphere which leads to label deterioration. Furthermore, hood storage causes the loss of valuable laboratory space, has no security provisions and may create hazards due to the presence of incompatible chemicals. Use of a hood for storage is discouraged.

Often a stockroom refrigerator of the standard home type is used for storage. This creates a hazard when certain flammable or explosive materials are stored in it. This type of refrigerator has numerous open type switches which can spark and ignite explosive vapors. If a refrigerator is used for this purpose, it should be the laboratory grade explosion-proof variety.

Store all materials in containers that are easily handled and resistant in the case of corrosives. A detailed list of chemicals and their proper storage containers is available in Safety in the Science Laboratory (Christian, 1968) and Safety in the Secondary Science Classroom (NSTA, 1978).

A purchasing philosophy dictated solely by economic considerations can create storage problems. While bulk rates usually result in less unit expense, chemicals should not be purchased in such quantities that they will not be used in a reasonable amount of time. Before any chemical is stored, the label should be checked to ensure that it clearly states what the material is, the type and severity of any associated hazards, precautionary and treatment procedures for the hazard and the date it was received.

The second area relative to the safe use of chemicals involves proper disposal techniques. The importance of protecting our environment from chemical pollution negates the wholesale use of dilution to dispose of chemicals down the drain. Small amounts of dilute acids, bases or salt solutions may be flushed down the drain with large amounts of water, but be sure that all materials are water soluble, non-toxic and in concentrations well below the threshold limit.

Solid materials that cannot be flushed because of their insolubility or toxicity should be disposed of in crockery storage jars with protective lids. Flammable solids should not be placed in these containers. Once the waste is collected it can be disposed of in a land fill or other appropriate technique as indicated in the publication Laboratory Waste Disposal Manual by the Manufacturing Chemists Association (1973). A partial list of materials that can be disposed of in a land fill or released to the air follows.

Argon
Asphalt
Batteries, dry cell
Boron
Bromochloromethane
Calcium carbonate
Calcium oxide
Carbon black
Carbon tetrafluoride
Chlorobromomethane
Chromium
Crude lime
Dichloromethane
Epoxy resin systems
Ferrosilicon
Helium
Hexachloroethane
Hexafluoroethane
Hydrogen
Lamp bulbs
Metal scrap
Molybdenum, insoluble
  compounds
Neon
Nitrogen
Nitrogen fertilizers

Nitrogen trioxidel
Osmium tetroxide
Oxygen
Ozone
Paint
Pyrethrum
Resins
Rubber
Scrap glass
Scrap stoneware
Silica
Sludges
Stone, alberine

Sulfure
Sulfur hexafluoride
Tar
Tetrabromoethane
Tin, organic compounds
Titanium oxide
Tremolite
Urea
Xenon
Yttrium
Zinc oxide
Latex
Magnesium oxide

The third area relates to chemical toxicity; toxic referring to those materials that cause damage to humans. A representative classification of the level of health hazard is nuisance, irritant, corrosive, anesthetic, allergen, carcinogen, mutagen, teratogen, toxin and central nervous system depressant. Often the safety hazard of a chemical is enumerated and its potential as a health hazard ignored. The volatility and flammability of carbon disulfide are emphasized, for example, but carbon disulfide is also highly toxic and may cause damage to the liver, kidneys and central nervous system. Chemical entry to the human organism occurs through the digestive tract, respiratory tract or skin. The respiratory tract is the most common entry pathway. Some substances have fumes or dust which are toxic when inhaled.

Examples

Acetic acid (concentrated)
Ammonium hydroxide
Benzene
Bromine
Carbon disulphide
Carbon monoxide
Carbon tetrachloride
Chlorine
Formic acid
Hydrochloric acid
Hydrofluoric acid
Hydrogen sulfide gas

Mercury
Nitric acid
Nitrogen oxides
Plastics
Perchloric acid
Potassium hydroxide
Sodium hydroxide
Sulfuric acid (hot or oleum)
Sulfur dioxide

In many cases direct contact with certain materials should be avoided because of damage to the tissue or because of the ability of the substance to penetrate the skin.

Examples

Bromine (liquid)
Carbon tetrachloride
Chromates
Dichromates
Formic acid
Potassium hydroxide
  (solid and in solution)
Sulfuric acid

Methyl alcohol
Butyl alcohol
Methyl acrylate
Hydrochloric acid
Hydrofluoric acid
Mercury
Nitric acid
Phosphoric acid (Hot
  Concentrated)

Perchloroethylene
Tetraethyl lead
Carbon disulfide

Benzene
Nearly all pesticides

Another concern are substances known to cause cancer in humans. **The Occupational Safety and Health Administration has identified the following carcinogens** (1976).

Benzidine
Bischlormethyl ether
Beta-Propiolactone
Dichlorobenzidine
Alpha-Naphthylamine
Beta-Naphthylamine
Acetylaminofluorene
Aminodiplenyl
Dimethylaminoazobenzene

Aminodiphenyl
Nitrobiphenyl
Nitrosodimethylamine
Methyl Chloromethyl
  Ether
Methylene (Bis)-
  Chloroaniline
Ethyleneimine
Vinyl Chloride
Asbestos

Many of these chemicals have more than one name. An article by J. Bradford Black, M.D., contains a list of these carcinogens and their synonyms. This was published in the September 1976 issue of the ***Journal of College Science Teaching.*** The list is also available from local chapters of the American Lung Association. As a companion to this list of known carcinogens, the National Institute for Occupational Safety and Health (NIOSH) has published a list of suspected carcinogens. This list is available through the Division of Technical Services, NIOSH, Cincinnati, Ohio 45226. All substances on these lists should be eliminated from the school laboratory.

The fourth area relative to the safe use of chemicals relates to unstable and/or incompatible chemical combinations. Frequent accidents occur because neither the student nor the instructor is able to anticipate the results of certain chemical combinations. This is not uncommon even among experienced chemists. Instructors should have available a list of unstable chemicals and incompatible combinations. A partial list of unstable chemicals and their properties is as follows.

Ether — easily forms explosive peroxides.

Ammonium nitrate — decomposes exothermically above 160 degrees Celsius, producing a large volume of gaseous products.

Formic acid — concentrated, it is unstable and has been known to explode.

Phosphorous-white — spontaneously ignites in air at temperatures above 30 degrees Celsius.

Ammoniacal silver nitrate solutions (Tollen's reagent) — may produce unstable products which detonate violently when disturbed.

Benzoyl peroxide — extremely unstable.

Nitrogen tri-iodide — shock sensitive when dry.

Picric acid, metal picrates, perchloric acid — very unstable.

Some incompatible chemical combinations follow.

Acetic Acid — Nitric acid, peroxides, permanganates, ethylene glycol, hydroxyl compounds

Acetone — Concentrated nitric and sulfuric acid mixtures

Alkali metals, (e.g., sodium or potassium) — Carbon tetrachloride, carbon dioxide, water, halogenated hydrocarbons

Ammonia, anhydrous — Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)

Ammonium nitrate — Acids, inflammable liquids, metal powders, sulfur, chlorates, any finely divided organic or combustible substance

Aniline — Nitric acid, hydrogen peroxide

Bromine, chlorine — Ammonia, petroleum gases, hydrogen, sodium, benzene, finely divided metals

Chlorates — Ammonium salts, acids, metal powders, sulfur, any finely divided organic or combustible substance

Chromic acid — Acetic acid, naphtaline, camphors, glycerin, turpentine, alcohol, flammable liquids in general

Flammable liquids — Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, the halogens

These chemicals should not come in contact with each other except under carefully controlled, safety consious conditions.

Hydrocarbons (e.g., propane, benzene, gasoline, etc.) — Flourine, chlorine, bromine, sodium peroxide

Hydrogen peroxide — Most metals and their salts, alcohols, organic substances, any inflammable substance

Hydrogen sulfide — Oxidizing gases, fuming nitric acid

Iodine — Acetylene, ammonia, hydrogen

Mercury — Acetylene, ammonia

Nitric acid (con.) — Acetic acid, hydrogen sulfide, inflammable liquids and gases

Oxalic acid — Silver, mercury

Potassium chlorate — Sulfuric and other acids, any organic substance

Potassium permanganate — Sulfuric acid, glycerine, ethylene, glycol

Sodium nitrate — Ammonium nitrate and other ammonium salts

Sodium peroxide — Ethyl or methyl alcohol, glacial acetic acid, carbon disulfide, glycerine, ethylene, glycol, ethyl acetate

Sulfuric acid — Potassium chlorate, potassium perchlorate, potassium permanganate, similar compounds of other light metals

An excellent publication for reference in this area is the Manual of Hazardous Chemical Reactions published by the National Fire Protection Association, 470 Atlantic Avenue, Boston, Massachusetts 02110 (1975).

What are some specific safety procedures with regard to microorganisms?

In working with microorganisms the same general safety procedures prevail that would be in force in any science laboratory. The instructor and students, however, should be aware of the additional hazard presented by the possible presence of infectious agents. Although high school students should not be allowed to work with known pathogenic organisms, all cultures of microorganisms should be treated as though they were pathogenic.

The most common sources of accidental infection occur from oral aspiration through pipettes, accidental syringe inoculation, animal bites, spray from syringes, centrifuge accidents, cuts from contaminated glassware, spilling or dropping pathogenic cultures, laboratory aerosols that may enter the respiratory tract and contact with infected animals and their cages. Follow microbiological laboratory procedures that minimize the above dangers. The transfer or inoculation of cultures using a pipette should be accomplished with a bulb. Avoid oral pipetting. The production of aerosols should be minimized by always discharging the pipette below the surface of liquids, neither by bubbling air into a liquid nor forcefully ejecting the liquid from the pipette. Immediately place used pipettes in a disinfectant solution, then autoclave before reuse. Avoid accidental syringe inoculation by ensuring proper animal restraint during injection. Again, reduce laboratory aerosols by discharging any liquids below the surface of the receiving medium and not by expelling excess liquid into the air. In using an inoculating loop, avoid aerosol production by allowing the loop to cool before insertion into the medium and by avoiding sudden movements that break the loop film. A centrifuge is often used to separate cell suspensions from the medium. Inspect all tubes to guard against breakage, and fill the centrifuge cups with disinfectant as a precaution should breakage occur.

In sampling for microorganisms to inoculate cultures, be aware of the potential presence of pathogenic organisms taken from field samples such as soil or untreated water. Exercise care not to contaminate a culture by coughing or sneezing or by prolonged exposure to the air. Take care that excessive distribution of spores and pollen does not occur in the classroom because of possible allergic reactions. Tape closed culture dishes that are passed around the classroom or left out for viewing. If a culture is accidentally spilled, clean the area with a strong disinfectant. All old cultures should be autoclaved before disposal. Although liquid disinfectants are useful, do not rely on them for complete sterilization.

What are some specific safety procedures and guidelines when working with plants and animals?

The use of living organisms, both plants and animals, in the classroom can be a motivational tool as well as a vehicle for understanding the concept of life and life processes. The use of living organisms does, however, introduce another spectrum of potential hazards and a new list of teacher and student responsibilities.

All plants should be thoroughly researched in order to know their toxicity. Parts of the same plant can have different properties. Therefore, in working with plants, never place any part of the plant in the mouth or rub the sap or fruit juice on the skin or into an open wound. Avoid inhalation or exposure of the skin and eyes to smoke from any burning plant or plant parts. Be knowledgeable of the proper recognition procedures for plants. Never pick any strange wild flowers or cultivated plants unknown to you. The following list from the ***Oakland County Science Safety Series Reference Guide for Biology*** (1977) indicates some plants known to cause reactions.

A complete reference is Human Poisoning from ***Native and Cultivated Plants,*** James W. Hardin and Jay M. Aerona, Duke University Press, Durham, North Carolina, 1977.

When working with seeds, be aware that a student may consciously or unconsciously place a seed in his or her mouth. This may create a danger from ingestion of the seed itself or from a coating of hormone, fungicide or insecticide. Do not use chemically treated seeds for classroom instructional activities. When working with pollen or spore producing plants; avoid unnecessary spread of pollen grains and spores which can result in bronchial inflammation or other allergic responses.

In working with animals in the laboratory, the

Plants Known to Cause Reactions

Apple trees — seeds
Autumn crocus, — (Star of Bethlehem) - bulbs
Baneberry — berries
Black locust — bark, sprouts, foliage
Bleeding heart (Dutchman's breeches) — foilage, roots
Crab apple — foliage, seeds
Daphne — berries
Death camas — all parts
Dieffenbachia (dumb cane, elephant ear) — all parts
Elderberry — all parts except fruits
English holly — berries
Foxglove — leaves
Golden chain — bean-like capsules in which the seeds are suspended
Honeysuckle — seeds
Horse chestnut — leaves, flowers and seeds
Hyacinth, narcissus, daffodil — bulbs
Iris — undergrown stems
Jack in the Pulpit — all parts, especially roots
Jessamine — berries
Jimson weed (thorn apple) — all parts
Lantana camary (red sage) — green berries
Larkspur — young plant, seeds
Laurels, rhododendron, azaleas — all parts
Lily of the Valley — leaves, flowers
Maidenhair trees (ginkgo biloba) — fruit
Marsh marigold (uncooked) — all parts, sap
Mayapple — green apple, foliage, roots
Mistletoe — berries
Monkshood (wolfsbane) — fleshy roots
Moonseed — berries
Mushrooms — all parts
Nightshade — all parts, especially the unripe berry
Oak trees — foliage, acorns unless properly prepared
Oleander — leaves, branches
Peach trees — leaves, seed
Pear trees — leaves
Plum trees — leaves
Poinsettia — leaves
Poison oak, ivy, nettles, common buttercup — all parts
Pokeweed — berries and roots
Potato — vines and foliage, green tubers
Privet (common) — berries and leaves
Rosary pea, castor bean — seeds
Rhubarb — leaf blade
Toadstools and related fungi — all parts
Tomato — vines, foliage
Water hemlock — all parts
White snakeroot — foliage
Wild carrot — foliage
Wild cucumber — seeds
Wild and cultivated cherry trees — twigs, foliage
Wild radish — flowers, fruits, stalks
Wisteria — seeds, pods
Yew — all parts

teacher should be aware, in addition to general safety procedures, of the psychological ramifications of animal experiments and should take steps to alleviate any misunderstandings. This necessitates that an adult supervisor assume the primary responsibility for experiments involving animals. The teacher should take precautions to ensure that animals used for experimental purposes are lawfully acquired and kept in strict compliance with federal, state and local laws and regulations.

Animals must receive humane treatment. Animals should be caged to avoid animal bites to students and to protect the animals from improper handling by students. Instruct students in the proper handling procedures and be sure they wear protective gloves or clothing as appropriate. Special handling requirements are necessary if the animal is pregnant, with young or hungry. Treat any scratches or bites that are incurred promptly and isolate the animal for 10 days. Clean the animal care facilities frequently enough to remove animal wastes, control vermin and keep the concentration of pathogenic microorganisms at a minimum. Optimum housing conditions for each species should be maintained, including proper diet and sufficient water. Return cold blooded animals to a care facility that approximates their natural environment as soon as possible after handling, and handle turtles as little as possible because they may carry salmonella. Do not keep poisonous snakes, snapping turtles, disease-carrying insects and harmful spiders in the classroom. In animal experiments do not subject the animals to stress, pain or discomfort. Deficiency experiments should be conducted only to the symptomatic stage and should cease before debilitating the animal. Do not perform surgery on any living vertebrate. Eggs that have been manipulated during development should not be allowed to hatch. Obtain all animals from a reputable supply house; avoid bringing wild animals into the classroom. Any disposal of animals should be accomplished in a humane fashion.

The National Science Teachers Association has established a code of practice on using animals in the classroom. The details of this code can be found in the September, 1980 issue of ***The Science Teacher.***

Disease control is another area of responsibility in caring for animals. Diseases can be transmitted among animals, from animals to humans and from humans to animals. Animals can contract salmonellosis, influenza, tuberculosis and infectious hepatitis from humans. Humans can contract many diseases from animals. These danger signs include an unusual odor emanating from the cage, a sluggish or unresponsive animal, constant or unusual bickering among inmates, loss of appetite, an unhealthy pallor or color change in hair, eyes, or skin, unusual discharge from body openings, or frequent sneezing. An animal suspected of disease should be isolated, its quarters disinfected, and if the diseased condition persists, humanely destroyed.

What are specific safety procedures when using electricity?

The basic hazard when using electricity is that of being subjected to electrical shock. Electrocution can occur under a variety of circumstances. It is actually the amount of current that flows through the body that determines the severity of the shock. Severe shock hazards can therefore exist even when using relatively low voltages. The amount of current flowing through the body is determined by the interaction of the factors expressed in Ohm's law

$$\left(\text{current} = \frac{\text{voltage}}{\text{resistance}}\right)$$

Therefore, with a constant voltage, the current that flows through the body increases as the resistance decreases. The body has a fairly low resistance but dry skin has a high resistance, about 500,000 ohms. Conditions that allow more than 10 milliamps to flow through the body will cause a painful shock. Conditions that result in a flow of from 100 to 200 milliamps may cause severe burns and unconsciousness. This is usually not fatal if treated promptly. Conditions that result in a current flow about 200 milliamps are usually fatal. The severity of the shock is also related to the nature and area of the contact surface, the time of contact and the pathway that the current takes through the body.

Electrical current flow has potential hazards for shock effects and heating effects. Because of the relatively high resistance of dry skin, the low voltages commonly encountered in using ordinary chemical dry cells are much less likely to produce dangerous or even uncomfortable shock. The relatively low resistances encountered in wired circuits can allow high current to flow even with low voltages, thus producing elevated temperatures capable of producing fire hazard and skin burns.

Electrical safety procedures involve controlling conditions so that electric current does not flow through the body. The standard 110 volt power line can be very dangerous. Electrical circuits and equipment should be handled only with dry hands. Moisture on the skin reduces its resistance from about 500,000 ohms to 1,000 ohms, creating a shock hazard. Electrical equipment should be handled only on a nonmetallic floor. Rubber mats are preferrable and the floor must be dry. The teacher or students should be sure that the person is not grounded nor in contact with any grounded items. The following is a partial list of additional procedures.

1. Test all electrical equipment for current leakage and refrain from using equipment that produces even a slight shock. Check electrical equipment for approval by the Underwriter's Laboratories or some other recognized testing lab.
2. Shield all live electrical switches and connections. Clearly label all switches and circuit breakers for the open and closed positions, and be aware of the location of the main breaker for the laboratory circuits.
3. Do not touch circuit parts with the power on. Use tools with insulated handles, and check all circuits used by students before current is allowed to flow.
4. When assembling circuits connect the live portion last; when disassembling disconnect the live portion first.
5. When plugging in equipment beware of sparks from a possible short circuit. When removing plugs pull by the plug, not the cord.
6. Do not connect appliance, equipment or extension cords on circuits intended for illumination only. Make sure that all electrical appliances and equipment are properly grounded.

The major information sources for the above were the ***Oakland County Reference Guide for Physics and Physical Science*** (1977) and ***Safety in the Secondary Science Classroom*** (NSTA, 1978). An additional source is the ***Modern Chemical Technology Guidebook for Chemical Technicians,*** American Chemical Society, Washington, D.C. (1970).

What are some specific safety procedures when using lasers?

The main hazard when working with lasers is potential eye injury. Even low laser power can cause retinal burns. If the area involves the macula, fovea or optic nerve, severe permanent damage may result. Additional laser hazards involve the potential for first and second degree burns as a result of exposure to beams from high-powered solid state or junction lasers. Electric shocks and burns may result from inadvertant contact with the input power or from a capacitor discharge. X-rays may be given off by some equipment. Burns can result from contact with liquid gas coolants.

Even the lowest power laser light should be avoided from direct beam exposure to the eye. Potential hazards of laser beams to the eyes are dependent on the laser power, beam diameter, distance from the beam, the color of the light, the angle of the beam, the focal length of the eye and the diameter of the eye opening. Therefore, reduce the optical power to the lowest level necessary to accomplish the instructional objective. A .5 milliwatt Helium-Neon laser is the maximum required for high school demonstrations. Keep the general illumination of the room high so that the pupils of the eyes are not dilated. All optical components should be rigidly fixed. All reflective objects should be removed from the anticipated laser path. All personnel should remain away from the sides of that path. Use a cover to block the beam when it is not in use. Privide security by equipping the primary circuit with a key switch. If at any time the interaction of the above stated factors exceeds threshold limits, wear glasses certified as protection for lasers. The ***Oakland Reference Guide for Physics and Physical Science*** (1977) indicates that exposure of the retina to radiation of one millijoule per cm^2 for one millisecond from a ruby laser has caused retinal burns. For additional procedures see the ***Handbook of Laboratory Safety***, Second Education, The Chemical Rubber Company, Cleveland, Ohio (1971).

What are some specific safety procedures when using model rockets?

The Federal Aviation Agency has established regulations concerning the launching of model rockets. In all cases rockets must be operated so as not to create a hazard to persons, property or other aircraft. The following guidelines were adopted from the ***Oakland County Reference Guide for Physics and Physical Science*** (1977).

1. The total rocket weight, including the engine should not exceed 16 ounces.
2. There should be not more than four ounces of fuel in the rocket engine at the time of the launch.
3. The rocket should be designed for reuse with a system to slow the rocket's return and thus minimize damage.
4. The rocket should be constructed for maximum inflight stability with a minimum of metal parts.
5. The rocket should not contain an explosive or pyrotechnic warhead.
6. The engine should be commercially prepared with all fuels already mixed. The engine should be incapable of igniting or exploding at temperatures of less than 170 degrees F. Spontaneous combustion should not occur in air, under water or glycerine or when subjected to shock or pressure.
7. The launch area should include 5,000 square yards and, when approximating a rectangle, have no side less than 50 yards. The flight area should be free of high voltage lines, major highways, water towers, multistory buildings and other obstacles.
8. Launch ignition should be accomplished electrically by remote control. Persons in the launch area should be warned when the launch is imminent.
9. Rockets should not be launched in cloud cover or at night. At launch time the wind speed should not exceed 20 miles per hour and visibility should never be less than 2,000 feet.
10. A launch area cannot be used if it is within four miles of the boundary of any airport.
11. The launch angle should be between 60° and 90° from the horizontal. An adult should inspect the rocket and launch area prior to flight and supervise the launch.
12. The rocket cannot be used for a fireworks display.
13. Unmanned rockets cannot be launched unless prior notice has been given to the Federal Aviation Agency Air Traffic Control facility as indicated by F.F.A. regulation Volume VI, Sec. 101.25.

Conclusion

These regulations and restrictions should not discourage the science teacher from creative teaching, experimentation and field trips. Careful planning and a liberal dose of common sense will make laboratory accidents unlikely.

Chapter V

The Nature of the Secondary Science Teacher

What qualities make a good teacher? What qualities are lacking in a poor teacher? These questions were asked of students in a poll conducted in cooperation with the National Association of Secondary School Principals. Students responded that good teachers work as hard as students, read what students write and point out the flaws, tell students the reasons for their grades, have boundless enthusiasm and yearn for knowledge themselves. They assign meaningful tasks, but not busy work; are authorities without being authoritarian; have absolute control of the class; are demanding of their students; and challenge students to perform to the best of their ability. Students said that poor teachers hold students in contempt, are negative and fault finding, show favorites, talk about themselves and their personal lives, are sarcastic to students, are "palsey-walsey," often try to be "cool" and popular with students, don't plan well and their instruction lacks purpose.

This chapter is concerned with some of the skills and strategies a science teacher should have to be effective. Not all aspects of the psychological and physical aspects of science teaching can be covered here, nor can all of the various teaching strategies and evaluation procedures be presented.

Interpersonal Skills

Teachers are today better educated. As individuals, and as a teaching force, they have more expertise in their respective areas. They have more knowledge about managerial decisions and about the competence of management personnel who supervise their performance. Authority in a bureaucracy assumes that there is a fairly even distribution of authority over a hierarchy of positions where each superordinate position has power over subordinates. Professional authority presumes an informal relationship where the distribution of authority rests solely on demonstrated knowledge or competence. Teachers are subject to both types since they are professionals in a bureaucracy. Teachers want principals to work with them prefessionally in matters of curriculum and instruction, but they also want them to exercise administrative authority to control student behavior. Frequently, the administrator either ignores or punishes professional behavior by the teacher. It is this professional vs bureaucratic conflict that leads to teacher dissatisfaction with how the school or school system is run.

The effective administrator and supervisor will find that the best way to work with people is by taking the cooperative approach. Even so, teachers are often faced with administrators who are hard-nosed; who say, "Do this because I say so." Some teachers may comply, either willingly because they agreed with the decision or resentfully. Other teachers will simply throw up their hands and leave the teaching profession, at least in spirit. The creative teacher who feels compelled to accept prescribed methods may eventually despair and give up teaching entirely. Bolder teachers will speak out, resist the administrator and set up cold war conditions. Everyone should realize that the function of administrators, supervisors and teachers is to work together for the good of the students and not for their own glory.

A science education program is no more effective than the combined efforts of the total teaching staff. For instance, the science teacher should work with the media staff to help them select science reference materials and audiovisual aids. Media specialists can be of invaluable assistance to science students who are working on research papers or reports. In this case the media staff should have advanced briefing as to the nature of the area of study so that they may be prepared to work with the students efficiently.

Since there is such a close relationship between math and science, working with members of the math department to develop concepts that are common to both disciplines is natural. There should also be coordination between the social studies and English departments. These areas may be incorporated into science in any number of ways.

Classroom Management

Teachers who have difficulty in the classroom fall into several categories. There is the teacher who is ineffective in the eyes of the supervisor, administrator and students, but sees himself or herself as effective. This teacher is identified by the poor progress of students, by a lack of rapport with students, by a lack of knowledge of the material being taught, by a lack of skill in presenting the material and by a lack of control of the classes. This teacher needs assistance in completing a self-inventory, highlighting strengths and weaknesses. Follow-up should include conferences, observations, consultation, evaluation, to emphasize strengths and to minimize weaknesses.

Sometimes the subject-centered teacher is seen as ineffective. Some teachers and principals believe that the subject matter is king and the learner should be adjusted to the subject rather than the subject matter adjusted to the student. The strict disciplinarian keeps all learners under his or her thumb, allowing no freedom for adolescent exuberance. Teachers who are having difficulty because of this attitude might review some of the principles of educational psychology, review learning theories, study the motivation of learners and the application of all of these theories to the classroom. Experienced teachers are often in greater need of supervision with respect to rigidity and subject-centeredness than inexperienced ones. Inexperienced teachers who have just recently completed their teacher preparation program usually know some of the latest thinking in education and in their teaching field and are not set in fixed ways of teaching.

Another category of ineffective teacher is the one who is ineffective and knows it. In addition, everyone in the school may agree that the teacher is ineffective. This type of teacher is most often defensive about his or her position and refuses to seek the help of fellow teachers, supervisor or administrator. The teacher claims that students are unmotivated, or that administrators are uncooperative, or that he or she is placed in the wrong grade or teaching field or in the wrong school. This teacher must be willing to accept suggestions from peers and supervisors. These people must, in turn, sense the insecurities of the troubled teacher and offer assistance.

The nature of science classes requires special discipline problems and methods of control. Science has many applications to daily lives of students. Motivation can be easier than in some other courses. Demonstration devices and laboratory equipment stimulate interest. Still, by its nature, the laboratory offers freedom of movement which may lead to discipline problems. Students with little self-discipline may find many opportunities to cause trouble. The teacher's control must be effective, but not so rigid that it sacrifices the opportunities for laboratory experiences.

Solving Behavior Problems

Behavior problems arise no matter how much teachers do to understand behavior problems, no matter how conducive the atmosphere is to learning and no matter how hard teachers try to prevent them. Every school will have its own policies regarding what teachers should do to handle discipline problems, and teachers should make certain they know the philosophy and attitudes of the local administration regarding disciplinary procedures. Most often teachers are expected to handle their own disciplinary problems, except in cases of severe problems such as classroom fights and outright disobedience. Minor types of childish behavior can be met with the simplest of techniques, a glare or stare or silence. The teacher should not make a big issue of petty misbehaviors. Often a quiet talk with the offending student about his or her behavior will suffice.

Conferences with parents by letter, telephone or face-to-face are also effective. Referrals to guidance counselors, school psychologists or outside agencies may be necessary in more severe discipline cases. When punishment by the teacher is indicated be sure that it is adjusted to both the offense and the offender and that it is fair, reasonable and sound. As often as possible teachers should make an effort to strengthen desirable behaviors in problem students with a good grade, a word of praise or perhaps something tangible. Inappropriate behavior should just be ignored. The teacher is a model for the learner when she or he expresses positive attitudes toward the process of learning. Students, too, serve as models for other students. Unfortunately some students may imitate the undesirable behavior of others if they observe them receiving reinforcement.

The best way to deal with behavior problems is to prevent them; then there is no need to worry about corrective measures. Often teaching styles provoke disciplinary problems. They may, for instance, repress every form of exuberance, or, on the other end of the scale, let students do as they please. Teachers need to display confidence. Teachers must set realistic objectives and use feedback to make sure they are using appropriate strategies. Analysis of student success and failures will determine if modifications in instruction are necessary.

Every teacher must examine the relevance of the curriculum and decide whether the needs of the students are being met. Classroom behavior is much less a problem if students feel that what they are there to learn is of some use to them now and in the future.

Begin Early

The first three weeks of school are important in establishing a teacher's management style. It has been reported that in the first weeks of school effective managers displayed a more workable system of rules and procedures which they taught to their students, gave more careful directions and monitored students more carefully, stopped inappropriate behavior more quickly and made clearer the consequences of appropriate and inappropriate behavior in their classrooms than did ineffective teachers. It is, therefore, important that teachers develop an efficient system for organizing procedures, rules and initial activities and teach this system to students at the beginning of the year and set the scene for effective classroom management for the year.

Teachers should gather as much information as possible about individual learners. Information about a student's background at home and at school can help explain some of the reasons why the child behaves as he or she does. Learning about potential students problems from other teachers is not necessarily a bad idea, but remember not to hold students' past against them. Students have difficulty in classrooms for many different reasons: conflicts with other students, personality conflict with a specific teacher, immaturity. In another setting, at another time, a problem student might be easy to get along with and interested in learning.

One of the goals of instruction is to make learning as enjoyable as possible. Therefore, it is not a good technique to assign extra homework to a particularly rambunctious class, or to threaten a noisy class with a test. The teacher should keep the class moving, involved in meaningful tasks and should avoid repetitive and unnecessary inconsequential activities designed to fill time.

The relationship between teaching and dramatics has been in much of the teacher-education literature. Unlike a TV or movie producer the teacher must consider the conditions of human growth and development. Youngsters tend to be restless and in need of movement and change. Their attention span is shorter than that of adults. Not all students are highly motivated, dedicated and interested in the material. Therefore, the teacher must devise means of attempting to increase interest in the topic of study. The key word here is variation—variation of stimuli and variation of learning activities for the group and the individual.

During every class a variety of stimuli effect responses in learners. The people in the room, lighting, furniture and equipment, the activity outside the door all have a bearing on the learning in the classroom.

The effectiveness of the use of gestures, the use of silence to secure attention have already been mentioned. Another technique is that of **focusing**—directing the attention of students to particular objects or concepts by the use of such statements as, "Keep this point in mind," or "Let's look at the picture on page 32." The teacher might also switch from oral communication—lecturing—to visual through the use of the chalkboard or overhead projector, and back again. By manipulating the stimuli and varying those stimuli the teacher can more readily gain and keep student interest.

Some special activities may be necessary for some individuals in the larger group. The individualization of instruction is one of the goals of the teaching process that has been described in countless articles and books. It is often made to seem like a simple task, but in reality it is an extremely difficult one. Education is a mass venture, we must handle individuals within groups and as members of a larger group. Given the mass nature of education we can partially adapt instruction to individual differences as we attempt to move to the ideal of individualization of instruction. Learning is an individual activity. Therefore, it behooves the teacher to put into practice whatever skillful means he or she can use to help differentiate instruction and make it more personal to the learner. Individualized instruction involves the following.

1. There are subgroups of students within the class. The teacher may create special interest groups or ability groups or remedial groups. Students may be grouped and regrouped for specific tasks and for special purposes.
2. The teacher allows choices. The teacher should make a habit of extending the opportunities for selection to the learners whenever possible. Students can be given a choice of subgroups to which they wish to belong, choices of learning activities which have equal value, approaches they would like to take to the study of a topic and resources they would prefer to use.
3. The teacher provides for independent study. Students who are mature enough and interested enough to pursue a topic of study independently should be given the chance to do so.
4. The teacher differentiates questions to individuals on the basis of their particular interests and abilities. In question and answer sessions the teacher can vary the complexity of questions according to the abilities of the intended responder, thereby allowing students of all ability levels to respond.
5. The teacher provides differentiated assignments. Minimal assignments may be set for slower students and more difficult assignments for faster students or brighter students. Some other device may need to be used to motivate the faster learners to do the more difficult tasks, but the practice of bonus tasks or honors assignments sometimes helps.
6. The teacher uses resources of varying levels of difficulty. There should be supplementary text materials available for varying levels of readers. There should be materials which present the topic being studied in different ways so that if the treatment in the textbook is not clear students may approach the topic in another way.
7. The teacher makes use of learning resources outside the classroom. This might include field trips, the use of reading clinics, learning resource centers, etc.

Most teachers assign homework. When making assignments for the next day, be certain that the assignment is clear to all students. Take enough time during class to make tasks understood. The assignment should be on work which the class has already covered, or which the teacher is certain the learners are able to do. The teacher should be familiar enough with the task to be able to anticipate difficulties which students may experience and give suggestions on how to overcome them. Assignments should be a reasonable length, keeping in mind that students have assignments from other classes as well.

Teaching Strategies

Science teachers should be prepared, organized and have direction and purpose for their teaching. There is no substitute for a well-prepared lesson. Start organizing the science program by developing a big picture, determining the sequence of the program for the year. This may simply mean breaking the year's work into units and then into individual lessons. Effective science teachers use a variety of teaching methods—choose the best for each lesson keeping in mind the questions, "What do I want to teach?" and "How can I best teach it?"

In science classes it is important that **thinking** be emphasized over memorization. This is both a curricular problem and an instructional one. Some memorization will be necessary, but the teacher should aim for higher levels of cognition and move away from students' regurgitation and recapitulation of facts. The use of the scientific method—or problem solving—is the principal route to learning. Teachers hear a lot today about teaching by inquiry, or teaching the discovery method. Sometimes these two terms are used interchangeably, but they can be differentiated.

Discovery occurs when an individual is mainly involved in using mental processes to discover some concept or principle. The discovery method can be summarized as involving these processes—observing, classifying, measuring, predicting, describing, inferring. There are four reasons for using this approach to teaching. 1. The student learns and develops the mind only by using it to think. 2. As a consequence of succeeding at discovery, the student receives a reward (a grade, perhaps). 3. The student learns the techniques of making discoveries by having opportunities to discover and learns how to organize and conduct investigations. 4. The discovery approach aids in better memory retention.

Inquiry is the process of originating and investigating problems, formulating hypotheses, designing experiments, gathering data and drawing conclusions about the problem's solution. The processes of inquiry include originating problems, formulating hypotheses, designing investigative approaches, testing out ideas, synthesizing knowledge and developing attitudes. In addition to the reasons for discovery teaching, the inquiry approach has these additional reasons. 1. Instruction becomes student centered. 2. Inquiry learning builds the self-concept of the student. 3. The student's expectancy level increases. 4. Inquiry learning develops talents. 5. Inquiry methods avoid learning only at the verbal level. 6. Inquiry learning permits time for students to mentally assimilate and accommodate information.

Science is best taught as a procedure of inquiry. Just as reading is a fundamental instrument for exploring whatever may be written, so science is a fundamental instrument for exploring whatever may be tested by observation and experiment. Science is more than a body of facts. It is a collection of principles and a set of machines for measurement; it is a structured and directed way of asking and answering questions. It is not difficult to teach a student the facts of science, but it is a challenge to teach a student the facts in their relation to the procedures of scientific inquiry, and the intellectual gain is far greater than the student's ability to conduct a chemical experiment or to discover some of the characteristics of static electricity. The procedures of scientific inquiry, learned not as a set of rules but as ways of finding answers, can be applied without limit. Well-taught students will approach human behavior and social structure and the claims of authority with the same spirit of alter-skepticism that they adopt toward scientific theories. It is here that the future citizen who will not become a scientist will learn that science is not memory or magic but rather a disciplined form of human curiosity.

Classroom discussion and questioning are more likely to complement inquiry learning than the lecture method. In answering questions students learn to evaluate, analyze and synthesize knowledge, and the teacher receives feedback. He or she learns from student comments how much they understand about the topic, moving it rapidly when they understand and slowing down when they do not. A lecture-oriented teacher seldom realizes when students are understanding.

Inquiry-oriented teachers must remain flexible. Even though they have planned a series of questions there must be a willingness to deviate from them and to formulate new ones as interaction with students occurs. Spontaneous questions may be difficult to create at first, but through trying to develop good questioning techniques the teacher becomes more adept at devising them and is more likely to interact with the students.

Give Time for Thinking

Some teachers wait less than one second for students to reply to their questions. Research analyzing student responses revealed that teachers with longer waiting times, three seconds or more, obtained greater speculation, conversation and argument than those with shorter wait-times. It seems that the expectancy levels of students are more likely to change positively if they are given a longer time to respond. A longer wait time also has advantages for the teacher. It gives the teacher time to hear and to think, and as wait-time increases teachers begin to show more variability in the kinds of questions they ask.

Questioning sessions should be planned. It is a skill which can be developed by following a few rules.

1. Since questioning is essentially a verbal, cognitive type of activity, the teacher should strive to raise the questions to the highest possible level of the cognitive domain. Too often teachers ask questions that require only a yes or no answer. Such responses do not encourage thought nor do they give students practice in organizing ideas and opinions. Questions at the lower cognitive levels may sharpen the memory process and should not be eliminated entirely, but they do little to develop the more important abilities. A sample of questions following Bloom's Taxonomy may be found at the end of this chapter.
2. Questions should be phrased clearly and in language the learner will understand. The importance of using language geared to the level of the learner is also important in any classroom discussion. Questions should be clear and in the teacher's own words, and not out of the textbook. Questioning should be considered as supplementary to text materials and students should be expected to answer in their own words instead of repeating the language of the text.
3. Teachers are concerned with the development of listening skills as well as speaking and comprehending skills, they should not develop the habit of repeating the questions and answers given by students. They should speak loudly and clearly enough so that students can hear. Repeating questions encourages students to daydream and wait for the second go around. Repetition may be necessary only when it is apparent that students have not understood the question.
4. Questioning sessions should consume only a portion of a lesson. Long question and answer sessions may defeat the purpose for which the questions was intended. One technique often used to liven up a question session is to turn the situation into a game. By creating teams to field questions the teacher can introduce a competitive spirit. This technique is adaptable only for the lower type questions and is too awkward for more complex and probing types of questions.
5. The affective learning which takes place along with the cognitive should be kept in mind by the teacher. Positive reinforcement of student responses in terms of words or gestures is important. When the responses are not correct, the student's **attempt** at responding should be rewarded.

The teacher should provide continuous and frequent opportunity for students to express themselves. Discussing and questioning should give students a chance to develop skills of listening, thinking, speaking and participating as members of a group. It is difficult for some teachers to restrain themselves and give students a chance to express their thoughts, but it is necessary. The teacher is not only concerned with expanding on the information in a classroom discussion, but with perfecting the discussion skills themselves. Therefore, it is important that the teacher attempt to provide opportunities for all learners to participate and not be content with participation by only a few students. Students should be encouraged to volunteer responses and to contribute illustrations and stories from their own experiences. The teacher needs to make the students feel that class participation is an important part of the day's lesson. They will then participate more frequently, especially when they are reassured that their opinions count for something and they do not fear ridicule or disapproval by the teacher or their classmates.

The teacher's task in classroom discussions is to keep the discussion on track. Students must learn to take turns in talking, listening while others are speaking. The teacher might allow students to serve in the role of moderator. A discussion can be started, stopped, moved along or turned in another direction by the wise use of gestures or movement on the part of the teacher. The teacher is conveying a message to students when she or he moves around the room and directs discussion from different areas. The teacher's movement acts as a stimulus for the learners to continue participating. When the teacher adopts an expression of puzzlement, the student knows that his or her response is not clear. Hand gestures, a look, nod, frown or silence can follow a student's comments, while an accepting "uhhuh," or bewildering "hmmmm" or rolling eyes showing amusement, are all ways of using verbal and non-verbal cues to draw out responses from students. The analogy of teaching to dramatics comes forth as the teacher uses these techniques to convey certain messages. Many of these cues are habitual traits with some teachers, while others may learn to develop their own by watching other teachers and by studying their own performance.

While the lecture method is often overworked, and given that teachers usually tend to talk far too much, lecturing can be an efficient means of getting across a large quantity of information to a large group of students in a short period of time. The lecturing can be improved by following a few guidelines.

1. Learners should be mentally mature enough to accept the mode of lecturing. The younger the child, the less receptive to lecturing.
2. Learners should have developed adequate listening skills to cope with the lecture. This is also directly related to the age of the student, but listening skills can be learned and developed.
3. Teachers must use language which the learners understand. They should not talk down to learners. Avoid using too much teenage jargon. Students often resent attempts by older folks to mimic street language. Students do not expect teachers to use their language, they expect teachers to play their roles as adults. Wise use of selected words may help get the message across, but overworking their slang may cause the teacher to lose the audience.
4. Every lecture should be planned. There should be a prepared outline that sets forth the key points to be made, key questions to be asked and illustrations to amplify key points.
5. Talk alone is not sufficient. The lecture should be supplemented with demonstrations or visual aids.
6. Provision should be made for feedback and follow-up. There should be time given for questions from the students. There also should be some type of evaluation to make certain that students have learned some of the points made in the lecture.

Teacher Demonstrations

A demonstration is the process of showing something to another person or group. In a demonstration a teacher can tell the students what is happening, but the demonstration can also be given inductively when the teacher asks several questions but seldom gives answers. An inductive demonstration has the advantage of stressing inquiry which encourages students to analyze and make hypotheses based on what they know. A demonstration can become an experiment if it involves a problem for which the solution is not immediately apparent to the class.

Demonstrations can be justified for these reasons.

- Less equipment and fewer materials are required.
- Time requirements are less.
- There is less hazard when dangerous materials are used.
- Teachers can direct students' thinking process.
- Teachers can show how to use and prevent damage to certain types of equipment.

There are several points to follow in planning an effective demonstration.

- Identify the concept and principles you wish to teach.
- If the principle is a complex one, subdivide it into concepts and be prepared to give some examples of each concept.
- Choose an activity that will show the concepts to be taught.
- Design the activity to involve as many students as possible.

- Gather and assemble the necessary equipment.
- Practice the demonstration at least once before class begins.
- Outline questions to be asked during the demonstration.
- Decide how to use visual aids to supplement the demonstration.
- Decide on an evaluation to use following the demonstration.
- Consider how much time the demonstration will take from start to finish.

Demonstrations may be presented in a variety of ways. The most common is probably the teacher demonstration, but it could also involve one or two students as assistants. It could also be a demonstration that involves a small group. Guest demonstrations by other teachers or persons from the community are helpful in relieving the tedium of classroom activities.

Laboratory Teaching

The teacher must consider the purpose of a lab exercise. If the only objective is to teach a specific bit of information, there is no point spending an hour or two of class time to demonstrate the facts. But learning facts is not the only legitimate function of the laboratory.

Bentley Glass stated

> *"The laboratory is the place where the work of science is done, where its spirit lives within those who work there, where its methods are transmitted from one generation to the next. One does not really learn science from books; one learns science by asking nature the right questions. And the laboratory is the place where one learns most readily what questions can be asked fruitfully, and how they must be put. It is where one learns why science insists on precise measurements, accurate observations, and conscieness and clarity in communication."*

Paul DeHart Hurd stated these ideas about the importance of lab activities.

> *"The major purpose of the laboratory is to help students develop an appreciation of the spirit of science and an understanding of scientific inquiry. To achieve these ends, the laboratory provides students with experience in collecting, systematizing, and discovering relationships among data in problem situations, and in using the results of their efforts to form concepts that in turn may furnish an interpretation of the natural world. This requires that students know more than answers—they must be able to distinguish between experimental evidence and personal opinion. Consequently, they must experience learning from observation and experiment, rather than from so much assertion and rote. Students also need to understand the relationship between the content of a subject and the process by which knowledge comes into existence and gets verified."*

Basically, the goals of learning in the laboratory can be summarized in four statements.

It is a place where students engage in a human enterprise of examining and explaining phenomena.

It is an activity that provides an opportunity to learn generalized systematic ways of thinking that should transfer to other problem situations.

It provides experiences that should allow each student to appreciate and to a degree emulate the role of a scientist.

The result of a laboratory instruction should be a more comprehensive view of science to include the orderliness of interpretations of nature and the tentative quality of its theories and models.

Many activities may be classified as lab experiences. A student who mixes grape juice and chocolate milk together to see what happens is experimenting even though he has no controls, no plans for making observations and probably will not draw any conclusions. Experiments may be complex attacks on problems. The simpler experiments are important because the approaches used are more readily adapted to everyday situations students encounter. Highly formal experiments have little application in the lives of young people.

Many science teachers restrict the term **experiment** to the type of investigation called a controlled experiment. In this type work every effort is made to control the factors involved. All factors but two are held as nearly constant as possible. Of the remaining two, one is varied and its effect on the other is determined. Many activities carried on in science laboratories and labeled experiments are no more than exercises with laboratory equipment. Some are designed just for this purpose, to familiarize pupils with certain pieces of equipment or with skills or specific principles.

The main difference between an experiment and an exercise is the information given to the students. In an experiment a student does not know what the results of efforts will be. In an exercise the student is told what the outcomes should be and how to attain them.

Standardized lab exercises are often misused because of the ease with which they may be conducted. The teacher needs only to provide the class with materials and directions and after this is done a few times, he or she is able to anticipate most of the difficulties students will face and needs to give little attention to the class during their work. Conscientious teachers, however, recognize the strengths and limitations of this type laboratory exercise. They may use them to enrich the program, but they provide other types of activities as well.

Scientific experiments, created and carried out by the pupils themselves, involve high level thinking. Students gain practice in recognizing and defining problems. Their ingenuity is challenged and exercised in devising methods of approach to a problem. Many students are not ready to undertake this type work, but are interested in following up suggestions given by the teacher or in reading outside materials. If allowed to work independently, they will gain experience and as they mature they, too, may undertake original research.

Many students lack ability for original work. These learners benefit most from standardized lab exercises by learning to follow directions, keeping good records and taking responsibility for careful work.

Teachers must expect to plan most of the laboratory work done in secondary school science. Newer science texts have accompanying lab manuals with various activities included. Publishers have also provided teachers with lab books to supplement their teaching regardless of the text being used. They are unquestionably time savers, but they are not necessarily efficient. Manuals tend to stereotype the lab program. They usually work toward uniform outcomes and do not provide for students with special interest and abilities, and make little or no provision for independent thinking. The use of lab manuals is justified in some situations but should not be the sole source of laboratory activities for the science classroom.

Regardless of the source of the laboratory activities, the teacher needs to carefully analyze the planned activity following these points.

1. Is the purpose easily understood?
2. Can clear-cut directions be given?
3. Are the procedures simple and direct?
4. Can results be obtained within a class period or suitable length of time?
5. Are the materials familiar to students?
6. Are the materials available?
7. Are applications of the findings obvious?

The selection of laboratory activities should be influenced by the need for concise, clear-cut directions. Many activities fail because the directions are too complex for students to follow. In some cases the teacher may want to rewrite and distribute directions for a particular activity.

Another factor is the length of time needed to attain results. Student attention will drift markedly after 15 or 20 minutes of one type of activity. Dead intervals may also occur. Serious problems of discipline can arise while students are waiting for water to boil or for filtration to be completed. When these types of activities are necessary it may be wise to provide supplementary activities to fill the time.

Make use of commonplace and familiar items. Students feel at ease with such materials, and they see the applications of their work to everyday situations more clearly—and may even see possibilities for doing similar experiments at home.

Independent Science Learning

Independent lab activities give students certain benefits that are not permitted by uniform lab assignments. Teachers, however, must know their students well before attempting to set up completely individualized lab activities. Individualization may begin in a limited way almost from the beginning of the school year. Students who show a special talent may be encouraged to begin work on a special problem. Individualization of lab work demands the teacher have a great deal of flexibility.

Lab work is best when each student is allowed to manipulate materials. Most students, however, prefer to work in groups and this is a definite advantage. Students working in pairs share experiences even though one may dominate the other to some extent. When students work in three's or larger groups some find it impossible to work with the actual materials. One student in each group is usually aggressive and dominates all activities. This leaves the others with little to do except observe passively, take notes or wander around the room. Careful planning is needed to provide worthwhile activities for each student in larger group settings.

During the actual lab period, after purposes have been defined and procedures outlined, the place of the teacher becomes a manager-facilitator. The teacher should move from group to group giving encouragement and clarifying procedures, but the teacher's presence in the classroom should not be required for the successful completion of the lab activity. The teacher should try to avoid interrupting the work of the class with announcements. When this happens the progress of activity will be broken and more often than not, time and continuity are lost.

Record keeping is important and there are many different ways students may keep records of their lab activities. Simple experiments need only simple records. Labeled diagrams are often sufficient, as are graphs and tables with or without additional notes. Duplicated sheets for use when collecting large amounts of data can be time savers. These sheets may also contain directions for gathering the data. However, such sheets encourage mechanical procedures and may discourage individual initiative.

Data are collected so that questions can be answered. Summaries and conclusions may be made orally, by filling in data on charts or by setting up exhibits. Conclusions should be limited to the conditions under which the experiments were carried out. Students should be urged to gather as much data as possible before drawing conclusions. When time is a factor they may pool their data to provide a broader base on which to draw conclusions.

Finding time to prepare for laboratory experiences can seem nearly impossible. The first step to solve this problem is to realize that the teacher does not need to do everything personally. Students may be assigned to the teacher to serve as laboratory assistants. Some students currently enrolled in the course are sometimes capable of preparing materials such as mixing solutions, preparing culture media, washing glassware and duplicating work sheets. Students can also take on the responsibility for bulletin boards and caring for plants and animals.

A most frustrating time for a science teacher occurs when the lab does not work the way it is supposed to. It takes a quick-thinking and innovative teacher to turn disasters into learning experiences. Teachers who understand science know the failure of an organism to respond, or the unexpected contamination of a culture should not imply that an experiment has failed. Seeking a reason for failure may provide a greater challenge and learning experience than would have occurred if the experiment had turned out correctly.

Another problem with conducting labs is that students do not like to prepare lab reports and teachers do not have enough time to read them. There is no reason why every lab exercise must be analyzed in writing, especially if the report is only a list of answers to questions in the text. Students need some mechanism for reviewing their experiences. An alternative to the written report is discussion. Students can tell what they did and listen to results of other teams and go beyond the concrete experience of the laboratory to the higher levels of synthesis and analysis.

This leads to another problem. If there is no written report, how are the students to be graded? A trained professional teacher should be able to recognize and evaluate learning behaviors. Observations collected as part of the daily class routine can serve as a guide for helping students learn more effectively. The teacher's judgment of a student's attitudes, work habits, scientific approaches and communication skills can be just as objective as the percentage of questions answered correctly on a lab report. The teacher might keep a log or journal on a student behavior in the laboratory—try to avoid the negative, but note the positive responses that students make to laboratory experiences.

Sharing the Laboratory

A problem that a lot of older schools have is the lack of lab facilities. The teacher might begin to resolve this problem by checking the possibility of sharing lab space with other teachers. If there is no lab room available, be inventive. Carry water in buckets or pans. Use protective plastic on the floor and desks when chemicals are being used.

Use alcohol burners instead of Bunsen burners. Try to work with the administration to plan modifications of a classroom to make lab work possible.

A more common problem teachers face is the lack of adequate equipment and supplies and a limited budget to buy consumables. First, try to convince the administration to reevaluate budget priorities to make more items available. If that does not work, seek help from students, other teachers and administrators to find ways to obtain simple equipment and supplies. Use table salt instead of sodium chloride. Brown sugar, fructose or molasses can usually replace sucrose. Babyfood jars can take the place of beakers and olive jars can substitute for test tubes as long as they are not to be heated. Milk cartons from the cafeteria make pots for growing seeds or containers to hold things. Unflavored gelatine can be used instead of agar. Use pie plates and baking dishes instead of Petri dishes. Make collecting nets from discarded pantyhose. Local greenhouses may be a source of free plants.

Try to look for lab exercises that require little equipment and few supplies. Most curriculum developers are well aware of budgetary constraints and many good labs are being written with the intent of reducing materials and keeping expenses at a minimum. (Some ideas for very inexpensive labs may be obtained from ***Science On A Shoestring*** by Herb Strongin, Addison-Wesley. While this book was intended for grades K-7 there are labs described that might be used in the high school.)

There may be other problems in trying to carry out laboratory activities, such as lack of storage space, need to move experimental setups from one room to another, vandalism, theft of expensive equipment. But in spite of all of these problems, students and teachers generally agree that lab activities are truly worthwhile.

Evaluation and Feedback

One of the important tasks all teachers face is that of setting standards for students and evaluating those students to determine the degree to which the standards have been met. Evaluation of student learning has informational as well as emotional consequences that influence students' learning and attitudes toward the learning process and themselves.

A defined performance standard sets the criterion for judging learning and instruction. Performance standards need to be set at frequent intervals during instruction. Student performance at the end of a semester or quarter tell teachers and students whether the learning and instruction were effective. A performance standard used as part of the instruction process lets the teacher know the extent to which learning and instruction were effective and the likelihood that future instruction and learning will also be effective. A preset, explicit standard tells students whether they have reached the goals set by the teacher.

Higher standards result in higher cognitive outcomes of some classes. But when standards are set too high student attitudes and interest in subject matter decrease. Most researchers do not regard 100 percent mastery of the materials as a necessary standard in the classroom. The standard should be determined by the level of achievement on one unit of learning which is necessary to assure student success on a subsequent unit.

Feedback tells students and teachers what has or has not been achieved in relation to a defined standard. When used only at the end of a semester or quarter, feedback has little value in improving student learning or teacher instruction. Errors have already accumulated and students may be less motivated to do something about the misunderstood or unlearned material. If feedback information is used after a long period of time it is not at all practical for the teacher to alter or strengthen the instruction or the instructional material. Timing is, therefore, essential to an effective use of feedback.

Feedback information should probably be provided to students at scheduled and defined points in a sequence of learning units, typically a period of about two weeks. At the end of the period feedback is gathered with the use of formative tests on the major objectives of the unit to help students determine what they still must learn. Assignments such as writing an essay, planning a project or experiments and observations may also be sources of feedback. Further, every question that a student asks or answers in class could indicate that the student either has difficulties or has reached an expected standard.

Science teachers usually evaluate students through the use of tests and laboratory reports, although other areas can be included such as notebooks and class participation. Teacher-made tests should stress the higher cognitive levels of Bloom's Taxonomy. They should be constructed from the teacher's list of behavioral objectives so that the evaluation will measure what was considered to be most important in the learning process.

Because mathematics and graphing are a large part of science, tests should use as many of these tools as possible. A good technique to determine if students understand graphing principles is to have them complete or devise a graph.

Competition and matching tests should be discouraged because of their emphasis on simple recall. Problem tests place more emphasis on self-instruction and can be used to motivate class discussions. In constructing a test the teacher should make a careful determination about how long the test will take to be completed and to make assignments for those who finish before the testing period ends to avoid discipline problems.

Feedback information can be effective if it is followed by corrective measures. Corrective procedures clear up misunderstandings students have already learned and allow them to relearn anything they have forgotten or failed to learn in the first place. One corrective procedure is to allow students to review the same content material as previously used, although reviewing the same material may reinforce the same mistakes and misunderstandings. Another corrective procedure may be the use of alternative instructional materials and methods. In some cases these materials may be used by the students following teacher review and explanation regarding the items missed by the majority of students. The most effective corrective procedure involves small study groups of two or three. Students find the questions they missed, and the students who answered them correctly take turns explaining the correct answers. If all students in a small group answered a question incorrectly, they refer to supplementary materials or seek help from the teacher or another group.

Students who have more self-confidence and a greater desire to learn become more involved as they progress in their learning. Soon they need less external help to reach a defined standard and may even take over the corrective procedures themselves. Effective use of feedback-corrective systems help teachers develop more confident students who not only achieve at higher levels but also who learn how to learn.

Teacher Evaluation and Certification

It is difficult to evaluate teachers. Are they to be evaluated by their relationships with administrators? How should appearance be rated? Are teacher memberships in professional organizations important? If so, should the number of memberships be more or less important than participation in the organizations? These traits must be clearly defined in an evaluation instrument, whether it is a self-evaluation or one to be completed by others.

The Georgia certification policy states that beginning teachers will be evaluated in two ways. First, they will pass a criterion-referenced test (the science test includes questions in biology, chemistry, earth science and physics). Second, they will score satisfactorily on an on-the-job assessment to be professionally certified to teach.

The Teacher Performance Assessment Instrument (TPAI) includes 20 competencies in five separate instruments: Teaching Plans and Material Instrument, Classroom Procedures Instrument, Interpersonal Skills Instrument, Professional Standards Instrument and Pupil Perceptions Instrument. The evaluation using these instruments involves a peer teacher, the principal and a staff person from the regional assessment office, all of whom have been trained in data collection procedures.

The teacher's initial certificate is issued to an applicant upon attainment of a passing score on the appropriate criterion-reference test and on completion of a bachelor's or master's degree from an approved teacher education program. A part of that teacher education program is that the applicant must have demonstrated a satisfactory performance of the TPAI: Student Teacher Form during the student teaching experience.

It is beneficial if, once in a while, a teacher does a self evaluation. The National Science Teachers

Association has developed a package of assessment instruments—"Our School's Science Curriculum," "Our School's Science Teachers," "Science Student/Teacher Interactions in Our School," "Science Facilities and Teaching Conditions in Our School." These could be of invaluable help in determining the effectiveness of a school's science program and showing areas where change is needed.

But adequate preparation, certification and evaluation techniques do not make a **professional**. The National Science Teachers Association has summarized its beliefs about the professionalism of science teachers.

> *The professional science teacher (a) is well-educated in science and the liberal arts; (b) possesses a functional philosophy of education and the technical skills, (c) continues to grow in knowledge and skill throughout his career, (d) insists on a sound educational environment in which to work, (e) maintains his professional status, (f) contributes to the improvement of science teaching, (g) takes a vital interest in the quality of future science teachers.*

Opportunities for professional growth are many. Graduate work, in-service workshops and institutes, committee activity—especially those involving curriculum development and evaluation—reading professional journals and scientific publications all help the science teacher reevaluate his or her effectiveness and keep abreast of new developments in science education. Membership in such professional organizations as the National Science Teachers Association, American Association of Physics Teachers, American Chemical Society, The National Association of Biology Teachers serve the science teacher in a variety of ways. Attendance at periodic meetings develops a sense of sharing and togetherness, the stimulation of meeting professional co-workers and gaining new ideas. The professional journals offered by these organizations provide a source of teaching ideas as well as ideas for improvement in classroom teaching techniques, materials, apparatus, resource books, information about scholarships and contests for students and teachers.

Being a science teacher is more than showing up every day before a class of students sitting in a "science" classroom. It is more than knowledge about science, being able to plan, use different methods and being enthusiastic about teaching. Being a science teacher means —

- **Courage** to continue your professional growth.
- **Commitment** to doing a better job tomorrow.
- **Competence** to fulfill your professional duties.
- **Compassion** toward your students.
- **Caring** for your own dignity, integrity and worth and for the dignity, integrity and worth of those in your care.

Using Bloom's Taxonomy to Classify Questions

Classification	**Sample Question**
Knowledge	How many legs has an insect?
Synthesis	What hypotheses would you make about this problem?
Application	Knowing what you do about heat, how would you get a tightly fitted lid off a jar?
Analysis	What things do birds and lizards have in common?
Comprehension	Operationally define a magnet.
Evaluation	If you were going to repeat the experiment, how would you do it better?
Valuing	What is your interest in earth science now compared to when you began the course?

Chapter VI

The Evaluation Process

Evaluation is an integral component of science curriculum development. This section of the secondary science guide presents an overview of evaluation applied to science student progress and programs of study. Major evaluation concepts are presented with suggestions for curriculum directors and teachers who wish to assess science program outcomes.

Variables

One of the greatest potentials for improving science programs lies in the wise use of data collected on many educational variables. Three logical categories of educational variables include input, process and output. Measurements on selected variables in each category provide useful information regarding adoption, adaptation, and implementation of secondary science programs.

Input

Input variables include program design, financial resources, physical facilities and materials. These variables are the given conditions upon which science programs are developed and implemented. It is within the parameters of these variables that curriculum directors seek administrative support for science program development and implementation.

Funds are appropriated with some assurance that they are essential and are to be used solely for the attainment of program goals and objectives. Based on this premise, the science curriculum coordinator must be able to maintain records of present and anticipated costs. Failure to measure input variables and to keep accurate records often leads to defeat of new program proposals. Disregard for assessment of input variables may result in funding cuts for established secondary science programs regardless of inherent value or promise to meet approved goals and objectives.

Process

Process variables include ongoing activities such as teacher performance in the classroom and utilization of science materials and resources. Because they are generally recognized as valid indicators of performance, the items in the ***Teacher Performance Assessment Instruments*** can be used as a measure of one process variable. Many instruments are described in the literature on teacher performance and can be adapted to virtually any science program.

Data on process variables can be used to identify relative strengths and weaknesses in teacher as well as administrative performance. These data can become the basis of well planned staff development activities. Effective staff development activities can, in turn, address areas of need thus strengthening the secondary science program.

Output

An abundance of information can be garnered from output variables. These variables include cognitive, psychomotor and affective student performance.

Cognitive domain. Measures of cognitive performance indicate the degree to which students exhibit knowledge of factual information. It can also indicate the degree to which students can apply problem solving skills, synthesize information and make judgments. Detailed descriptions of various levels of cognition and suggestions for developing appropriate instruments are not to be overlooked by enthusiastic curriculum directors and science chairpersons.

Psychomotor domain. Data on the psychomotor variable are helpful to curriculum directors and classroom teachers. Student performance which requires a large degree of hand-eye coordination may be considered as psychomotor. Instruments designed to collect data on the psychomotor variable may, for example, measure student ability to construct laboratory equipment. Other activities which are directly or closely related to psychomotor performance include making and recording observations, using measuring instruments, making graphs and properly using laboratory materials such as solvents, acids and other chemicals. Specific suggestions for constructing items designed to measure performance on the psychomotor variable are available through some county professional libraries, many public libraries, and all college libraries.

Affective domain. In addition to the cognitive and psychomotor variables, information can be obtained from the affective domain of student performance. The affective domain includes feelings, attitudes, and value systems. Teachers and curriculum directors would be wise to develop instruments to measure the effects science programs have on students' attitudes and preferences. The importance of this task lies in the fact that teacher performance, texts, and science programs project their own values. Not only are measures of affective performance essential components of the evaluation process, they provide data on the nature of values and their effects on secondary science students. Such data may be required by parent groups or boards of education. Several excellent publications address the problems and promises of affective measures.

Measuring Student Progress

Instructional and supervisory personnel have a genuine interest in student progress. However, roles in the evaluation process differ substantially. A curriculum coordinator, for example, will spend much time and energy on ascertaining the degree to which students are progressing with regards to systemwide science goals and objectives. On the other hand, teachers find themselves directly involved with the task of developing instruments sensitive enough to measure the degree to which their students are attaining goals and objectives for a given instructional unit.

A common task for science teachers as well as curriculum directors is that of determining and clearly stating goals and objectives. This task is a prerequisite function to the construction of teacher-made tests or the selection of standardized tests.

Goals

Goals are broad statements of ideas and values. (14) They may originate from within the school community or they may be adopted from sources including the American Association for the Advancement of Science, the National Science Teachers Association and its affiliates such as the National Association of Biology Teachers.

An example of a goal for secondary physics or chemistry could be expressed in the following manner. "Students will know when and how to use precision measuring instruments." Although the goal statement doesn't name the specific measuring instruments or tell how they are to be used, the goal does state that students will certainly know when and how to use the instruments. Objectives, in contrast to goals, specify the instruments as well as state the degree of precision expected by students.

Objectives

Objectives are more specific than goals in that they state what the student should be able to do as a result of having received instruction and laboratory experiences. Objectives are usually referenced to student performance rather than teacher performance and are referred to in the literature as behavioral objectives.

Behavioral objectives state what students will do, the conditions under which students will perform and how well students must perform. Consider the following example.

> Using an analytical balance, student will be able to weigh the total mass of three unknown samples. There will be two opportunities in 45 minutes to report the correct (± .009 g) mass. Incorrect results on a second attempt will result in a grade of "U."

Analysis of the objective yields the following components.

- **Observable performance** — weigh
- **Conditions** — using analytical balance, three unknown samples, two opportunities, 45 minutes
- **Criterion** — ± .009 g

Observable performance. This aspect of behavioral objectives forces the teacher to clearly specify what the student can be observed doing. For example, a student can be observed breaking and fire polishing glass rods. These are therefore, observable terms. Some common infinitives include to write, to list, to spell, and as seen in our example, to weigh. Actually any word may be used if it denotes a clearly observable behavior or can be defined operationally. Additional examples may be useful to teachers and curriculum directors who wish to begin or continue to upgrade course syllabi.

Conditions. Conditions of performance refers to materials needed by students to perform the objective. Time and place should also be included as part of the conditions for performance. A clear statement of conditions is essential when there are circumstances not normally considered in classroom or laboratory activities. For example, many grade related problems can be avoided by letting students know the number of opportunities and the amount of time they have to complete a task.

Criterion. A criterion is the degree to which performance must occur before one can say that an objective has been attained at a minimum level. The minimum level may not be the same for every student; it may be higher for some students. The point is that an absolute minimum level of acceptable performance must be stated. If performance falls below the stated level, the performance is judged as inadequate and the objective is not attained.

Types of Tests

Measuring student progress requires that decisions be made regarding the type of test to be developed or purchased. For example, if a teacher wishes to select students for an advanced science course the referent may be the group's arithmetical average. In this case, the teacher might consider a norm-referenced test. Such tests are generally designed to discriminate among students and to spread scores over a normal distribution. This is the appropriate type of test if there is a need to compare a student's achievement to a group norm.

When the test referent is a specified performance criterion, the test is referred to as a criterion-referenced test or CRT. Teachers who use CRTs are not comparing an individual's performance to a national or local norm. On the contrary, the teacher is assessing what has been learned with reference to some previously stated performance level. For example, a student may attain an objective by correctly writing the names of 40 chemical elements when given their symbols. In this example the criterion is 40 correctly spelled names. The criterion is not dependent on what a student's peers may have done in terms of a class mean or average.

Secondary science teachers and curriculum directors should take note of the advantages of CRTs. Although NRTs are widely used, the value of using CRTs is notably appreciated in efforts to determine the effectiveness of a science program.

A listing of many commercially published tests can be found in all college and some public libraries. Information on grade levels, unit costs and extensive critiques are available from the same sources. Principles and procedures for selecting tests can be found. An especially useful document which lists and describes only standardized science tests is available from the National Science Teachers Association.

Validity and reliability. When the type of test is selected and a specific instrument is being considered, the questions of validity and reliability are sure to arise. Basically, a valid instrument provides a measure of what the instrument is designed to measure. For example, an instrument designed to measure student knowledge of the development and function of the human skeletal system should not contain items which measure knowledge of the development and function of the respiratory system. If the manual of a commercially produced instrument does not address the issue of validity or if there is any doubt as to an instrument's validity, don't use it.

In addition to validity, the manual of any commerically prepared instrument should provide statistical information regarding test reliability. Although there are different kinds of reliability, it is generally understood to mean that essentially the same results should be obtained from the administration of an instrument to similar groups of students under similar circumstances. That is, scores should not vary greatly between testings for similar groups when instruction and external conditions are the same. Formulas for computing reliability coefficients and other statistics are explained in detail in some authoritative but inexpensive publications.

One way to enhance the validity of teacher-made tests is to construct test items which are keyed to behavioral objectives. A useful tool in this effort is a table of specifications.

Table of Specifications

A table of specifications (TOS) ties science subject matter content to specified achievement categories. A TOS aids the teacher in making decisions regarding the balance of subject matter to achievement categories found in corresponding behavioral objectives. These relationships are apparent in Table 1 which shows a TOS for a chemistry unit on compounds and mixtures. The focus is on five subject matter areas and three achievement categories.

The TOS in Table 1 indicates that 14 items will test student ability to recall specific factual information. Five of the 25 items will test for knowledge of specific facts regarding formation of compounds. Similar observations can be made about other subject matter areas and achievement categories by looking at the number of items in each cell. Column totals indicate the relative emphasis on various achievement categories. The TOS in Table 1 does not contain a category related to the affective domain. This is not to suggest a faulty TOS. On the contrary, one can

Table 1

Table of Specifications for a 25 Item Test On a Unit in Inorganic Chemistry (Compound and Mixtures)

Subject Matter Content Areas	Selected Achievement Categories		
	Knowledge of basic facts and concepts	Problem solving	Laboratory procedures
Formation of compounds	5	2	2
Formation of mixtures	3	3	
Physical properties of compounds	1		
Chemical properties of compounds	2		1
Chemical reactions	3	2	1
Number of items	14	7	4

only conclude that the teacher who developed this particular TOS did not wish to include affective items. It may be that such items were planned for a soon-to-follow test. It is wise however, to include one or more items of an affective nature at several points during a reporting period.

There should be a positive relationship between emphasis on achievement categories and content areas in a TOS and student activities as a part of classroom instruction and laboratory work. If this suggestion is followed, both validity and item construction are greatly enhanced.

Item construction. A major problem in item construction is writing items that are relevant. Items should be relevant to the content area and achievement category. Strict adherence to a well-developed TOS provides assurance that efforts to this end will be well worth the time spent.

The following steps should be useful as a guide to item construction.

1. Develop a Table of Specifications (TOS)
2. Select a cell in the TOS
3. Refer to appropriate behavioral objective
4. Decide on the item format (i.e., True/ False, Multiple Choice, Matching, Essay)
5. Write item keyed to appropriate behavioral objective

Application of the five step plan to the unit on compounds and mixtures is illustrated in the following statements.

. . . TOS completed (See Table 1)

. . . Cell selected (Formation of compounds/ knowledge of basic facts and concepts)

. . . Objective (Differentiate between compounds and mixtures)

. . . Item format selected (Multiple choice)

. . . Item written
Which one of the following is a compound?
A. Ice cream
B. Powdered sulfur
C. Water
D. Soil

This procedure is repeated until the specified number of items has been written. Additional instruction on developing a TOS and constructing items using a variety of formats can be found in the literature. Many suggestions and examples of item construction on various levels of the cognitive, affective and psychomotor domains are also in print. Procedures for refining items based on item analysis procedures should also be considered.

Science Program Effectiveness

Previous comments regarding student progress are also applicable to science program effectiveness. Two additional concepts which apply equally to measuring student progress and program effectiveness are formative and summative evaluation. These concepts give the curriculum director or external evaluator a broad perspective of the evaluation process.

Summative Evaluation

Summative evaluation addresses the question, "To what degree have the goals and objectives of the science program been attained?" Results of summative evaluation are condensed into a summary of the program's accomplishments supported by statistical and other evidence based on appropriate evaluation design. That summative evaluation parallels methodology common to good scientific research should make it all the more attractive to curriculum directors and secondary science classroom teachers.

Step-by-step procedures for conducting summative evaluation are indispensable to curriculum directors who are not evaluation experts. The following adaptation of a seven-step procedure developed by Tuckman should serve as an introduction to the major dimensions of summative evaluation.

1. State science program goals
2. State objectives in behavioral terms
3. Select or develop valid tests keyed to objectives
4. Identify samples of students including experimental, comparison or control or criterion groups
5. Administer test(s) and collect data on input, process and output variables
6. Analyze data using appropriate statistical procedures
7. Make recommendations based on analysis of data

A variety of experimental designs which fit within most of the seven-step procedure is described by Fitz-Gibbon and Morris. The designs include true control group with pretest-posttest or posttest only, nonequivalent control group with pretest-posttest, single group time series, nonequivalent control group time series and experimental group before-and-after. One or more of these designs are appropriate for providing evaluation data and conclusions for summative evaluation for any secondary science program.

Formative Evaluation

Formative evaluation addresses the question, "How well is the on-going program operating as it attempts to meet its goals and objectives?" Because formative evaluation is continuous, it provides feedback to the curriculum director and teachers about successes and difficulties in program implementation as they occur. The feedback is derived primarily from the following process variables—observation of support staff, program records and self reports. Methodology for measuring these variables are clearly outlined and exemplified in inexpensive sources. The Self-Assessment Kit published by the National Science Teachers Association is an excellent aid in formative evaluation.

Although formative evaluation tracks program implementation and provides a record of the program's developmental history, it may also use some of the research designs frequently used in summative evaluation. Thus, curriculum directors or other evaluators should become more knowledgeable of all the concepts presented in this section of the guide. More importantly, curriculum directors are well-advised to begin making plans to measure the effectiveness of present science programs and, most certainly, to begin developing plans to evaluate programs anticipated to be implemented in the future.

Lack of program evaluation in the past may have been due to inadequate resources and little time on the part of the curriculum director. Today, however, there are several evaluation resources, including consultants and agencies.

Summary

Evaluation of student progress and program effectiveness depends on valid and reliable information in input, process and output variables. An analysis of student achievement as an output variable reveals cognitive, affective and psychomotor domains of performance. Instruments can be developed to assess student performance in all domains. A table of specifications aids in this effort by depicting the proportion of test items keyed to various performance levels specified in corresponding behavioral objectives.

Norm- and criterion-referenced tests are commonly used to measure student progress and science program effectiveness. Tests constructed by teachers should reflect goals and objectives which are actually taught and embraced by a given program. If published tests are considered for adoption, efforts should be made to determine their validity and reliability before they are purchased. Potentially useful test batteries and items are readily available through many sources.

Formative and summative evaluation of science programs make use of information sources from input, process and output variables. Although summative evaluation places more emphasis on attainment of goals and objectives, formative evaluation provides program documentation and essential information on input and process variables. Accurate and detailed descriptions of program implementation are essential if modifications are expected to enhance secondary science program effectiveness.

Bibliography

American Association for the Advancement of Science. ***Science—A Process Approach: Commentary for Teachers.*** Washington, D.C., 1970.

Biological Sciences Curriculum Study. ***Biology Teachers' Handbook.*** New York: John Wiley and Sons, 1978.

Black, J. Bradford. "Carcinogens in the Schools," ***Journal of College Science Teaching,*** September, 1976, pp. 24-26. EJ 145 418

Bloom, B. S. (Ed.). ***Taxonomy of educational objectives: The classification of educational goals, Handbook I: Cognitive domain.*** New York: McKay, 1956, pp. 201-207.

Brown, Billye W. and Walter R. Brown. ***Science Teaching and the Law.*** National Science Teachers Association, 1969. ED 034 697

Bruner, J. S. ***The Process of Education.*** Cambridge, Mass. Harvard University Press, 1960.

Buros, O. K. (Ed.). ***Mental Measurements Yearbook.*** New Jersey: Gryphon Press, 1972.

Buros, O. K. (Ed.). ***Tests-in-Print II.*** New Jersey: Gryphon Press, 1974.

Capie, W., S. Anderson, C. Johnson and C. Ellett. ***Teacher Performance Assessment Instruments: A Handbook for Interpretation.*** Athens: University of Georgia, 1979 (Revised, 1980).

Carver, Fred and Thomas J. Sergiovanni. ***Organizations and Human Behavior: Focus on Schools.*** New York: McGraw-Hill Book Company, 1969.

Christian, Floyd T. ***Safety in the Science Laboratory,*** Bulletin 74. Florida Department of Education, Tallahassee, 1968. ED 026 255

Christensen, H. E., Ed. and T. Luginbyhl, Ed. ***Registry of Toxic Effects of Chemical Substances.*** U. S. Department of Health, Education, and Welfare, Public Health Service, National Institute for Occupational Safety and Health. Rockville, Maryland 20857. June 1975.

Christensen, H. E., Ed. and T. Luginbyhl, Ed. ***Suspected Carcinogens,*** A Subfile of the NIOSH Toxic Substances List. U. S. Department of Health, Education, and Welfare, Public Health Service, National Institute for Occupational Safety and Health. Rockville, Maryland 20857. June 1975.

Dean, R. A. and M. C. Dean ***A Proposed Science Curriculum K-12 Including Expected Proficiencies for the Elementary and Secondary Grades.*** San Diego County Department of Education, 1981.

DeVito, A. Science curriculum content selection. In Hans O. Anderson (Ed.), ***Viewpoints in Teaching and Learning.*** Winter, 1979, 55(1), 48-54.

Diederich, P. B. ***Short-cut Statistics for Teacher-made Tests.*** Princeton: Educational Testing Service, 1964.

Doran, R. ***Basic Measurement and Evaluation of Science Instruction.*** Washington: National Science Teachers Association, 1980.

Ebel, R. L. ***Essentials of Educational Measurement.*** Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1972, pp. 451-542.

Fitz-Gibbon, C. T. and Morris, L. L. ***How to Design a Program Evaluation.*** Beverly Hills, California: Sage Publications, Inc., 1978.

Frederickson, Clifford T. ***Handbook of Science Laboratory Practices and Safety,*** Revised. San Diego Schools, 1966. ED 023 607

Gafafer, W. M., Ed. ***Occupational Diseases, A Guide to their Recognition.*** U. S. Department of Health, Education, and Welfare, Public Health Service PHS Publication No. 1097. 1966.

Gephart, W. J., R. B. Ingle and F. J. Marshall, (Eds.). ***Evaluation in the Affective Domain.*** Bloomington, Indiana: Phi Delta Kappa, 1976.

Gilchrist, R. and Roberts, B. ***Curriculum Development: A Humanized Systems Approach.*** Belmont: Ferron Publishers, 1974.

Goodlad, J. I. ***School, Curriculum and the Individual.*** Waltham, Mass.: Blaisdell, 1966.

Gronlund, N. E. ***Preparing Criterion-referenced Tests for Classroom Instruction.*** New York: The Macmillan Company, 1973.

Handbook of Laboratory Safety. The Chemical Rubber Company, Cleveland, Ohio, Second Edition. 1971.

Hardin, James W. and Jay M. Aerona. ***Human Poisoning from Native and Cultivated Plants.*** Duke University Press, Durham, North Carolina, 1977.

Harrow, A. ***A Taxonomy of the Psychomotor Domain.*** New York: Longman, Inc., 1972.

Inhelder, B. and Piaget, J. ***The Growth of Thinking From Childhood to Adolescence.*** New York: Basic Books, 1958.

Irving, James R. ***How to Provide for Safety in the Science Laboratory.*** National Science Teachers Association, 1968. ED 027 220.

Katz, M. ***Selecting an Achievement Test: Principles and Procedures.*** Princeton: Educational Testing Service, 1969.

Kibler, R. J., et al. ***Objectives for Instruction and Evaluation.*** Boston: Allyn and Bacon, Inc., 1981, pp. 156-160.

Klopfer, L. E. Evaluation of learning in science. In B. Bloom, J. Hastings and G. Madaus (Eds.), ***Handbook on Formative and Summative Evaluation of Student Learning.*** New York: McGraw-Hill, Inc., 1971.

Krathwohl, D., et al. ***Taxonomy of Educational Objectives, Handbook II: Affective Domain.*** New York: Longman, Inc., 1964.

Kuslan, Louis I. and A. Harris Stone. ***Readings on Teaching Children Science.*** Belmont, California: Wadsworth Publishing Company, Inc., 1969.

Lovin, Tamar and Ruth Long. ***Effective Instruction.*** Association for Supervision and Curriculum Development. Alexandria, Virginia. 1981.

Mager, R. F. ***Preparing Instructional Objectives.*** New York: Harper and Row, 1972.

Manufacturing Chemists Association. ***Guide for Safety in the Chemical Laboratory,*** 2nd Edition. Van Nostrand Reinhold Company, New York, New York. 1972.

Manufacturing Chemists Association. ***Laboratory Waste Disposal Manual.*** MCA, Washington, D.C., 1972. ED 164 249

Meacham, Merle L. and Allen E. Wiese. ***Changing Classroom Behavior: A Manual for Precision Teaching.*** Scranton, Pennsylvania: International Textbook Company, 1969.

Meyer, E. ***Chemistry of Hazardous Materials.*** Prentice Hall, Inc., Englewood Cliffs, New Jersey. 1977.

Moored Balloons, Kites, Unmanned Rockets and Unmanned Free Balloons, Vol. VI, Part 101. Department of Transportation, Federal Aviation Administration, Washington, D.C.

Morris, L. L. and C. T. Fitz-Gibbon ***How to Measure Program Implementation.*** Beverly Hills, California: Sage Publications, 1978.

National Fire Protection Association. ***Hazardous Chemicals Data 1975.*** NFPA No. 49. National Fire Protection Association, 470 Atlantic Avenue, Boston, Massachusetts 02210. 1975.

National Science Supervisors Association. ***2nd Sourcebook for Science Supervisors.*** Washington, D.C. 1976.

National Science Teachers Association. ***Guidelines for Self-Assessment of Secondary School Science Programs.*** Washington, D.C. 1978.

National Science Teachers Association. "Code of Practice on Animals in Schools." ***The Science Teacher,*** September 1980. pp. 57-58.

National Science Teachers Association. ***Safety in the Elementary Science Classroom.*** National Science Teachers Association, Washington, D.C. ED 176 979

National Science Teachers Association. ***Safety in the Secondary Science Classroom.*** National Science Teachers Association, Washington, D.C. ED 176 979

National Science Teachers Association. ***Safety in the Secondary Science Classroom.*** National Science Teachers Association, Washington, D.C. 1978. ED 164 350

New York City Board of Education. ***Science Safety Grades K-12,*** Curriculum Bulletin, 1971072, Series 7. New York City Board of Education, Bureau of Curriculum Development, Brooklyn, New York 1972. ED 091 173

North Carolina Department of Public Instruction. ***Safety First in Science Teaching.*** North Carolina Department of Public Instruction, Division of Science Education, Raleigh, North Carolina, April 1977. ED 146 049

Oakland Schools. ***Oakland County Science Safety Series Reference Guide for Biology.*** Oakland Schools, Division of Instruction, Pontiac, Michigan 1977.

Oakland Schools. ***Oakland County Science Safety Series Reference Guide for Physics & Physical Science.*** Oakland Schools, Division of Instruction, Pontiac, Michigan, 1977. ED 174 475

Oakland Schools, ***Oakland County Science Safety Series Reference Guide for Chemistry.*** Oakland Schools, Division of Instruction, Pontiac, Michigan, 1977. ED 174 474

Oakland Schools. ***Oakland County Science Safety Series Reference Guide, Elementary.*** Oakland Schools, Division of Instruction, Pontiac, Michigan 1977. ED 174 472

Oliva, Peter F. ***Supervision for Today's Schools.*** New York: Thomas Y. Crowell Company, 1976.

Pella, M. O. ***Scientific Literacy and a Framework of Science.*** A paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Los Angeles, March, 1975. (ERIC Document Reproduction Service, No. ED 129 563).

Pescok, Robert L., Ed. and Kenneth Chapman, Ed. ***Modern Chemical Technology Guidebook for Chemical Technicians.*** American Chemical Society, 1970. ED 047 997

"A Good Teacher Is . . ." ***Exchange.*** Rockdale County Board of Education, Conyers, Georgia, May, 1981.

Rowe, Mary Budd. "Science, Silence, and Sanctions." ***Science and Children.*** Vol. 6, March, 1969.

Rusch, J. Science—a basic study. In Hans O. Anderson (Ed.), ***Viewpoints in Teaching and Learning.*** Winter, 1979, 55 (1), 1-10.

Safety in Handling Hazardous Chemicals Manufacturing Chemists, June, 1971. ED 047 997

Science—A Process Approach II. New York: Ginn and Company, 1974.

Shell Oil Company. Shell Chemical Safety Guide. 1979.

Simon, A. E. and Boyer, E. G. ***Mirrors for Behavior, an Anthology of Classroom Observation Instruments.*** Philadelphia: Research for Better Schools, Inc., 1970.

"Notice of Change in Teacher Certification." Teacher Certification Services, Division of Staff Development, Georgia Department of Education, Atlanta.

"Teaching Field Criterion-reference Tests, Development On-the-Job Assessment Development, Schedule for Implementation of Performance-based Certification." Mimeographed. Division of Staff Development, Office of Planning and Development, Georgia Department of Education, Atlanta, February 1979.

Stecher, D. G., Ed. ***The Merck Index.*** Merck & Co., Inc., Rahway, New Jersey, 1968.

Thurber, Water A. and Alfred T. Collette. ***Teaching Science in Today's Secondary Schools.*** Boston: Allyn and Bacon, Inc., 1968.

Trowbridge, Leslie W., Rodger W. Bybee and Robert B. Sund. ***Becoming A Secondary School Science Teacher.*** Columbus, Ohio: Charles E. Merrill Publishing Co., 1981.

Tuckman, B. W. ***Evaluating Instructional Programs.*** Boston: Allyn and Bacon, Inc., 1979.

U. S. Department of Health, Education, and Welfare. ***Safety in the School Science Laboratory, Instructor's Resource Guide.*** August, 1977. ED 157 701

Vargas, J. S. ***Writing Worthwhile Behavioral Objectives.*** New York: Harper and Row, 1972.

Wall, J. ***Standardized Science Tests.*** Washington, D.C.: National Science Teachers Association, 1981.

Wood, F. H., S. R. Thompson and F. Russell. Designing effective staff development programs. In R. Brandt and N. Olson (Eds.), ***Staff Development/Organization Development.*** Alexandria, Virginia: Association for Supervision and Curriculum Development, 1981.

Appendices

Course Outline — Biology

Course Objective	Essential Skills Objective
I. The Science of Biology	
A. Define Biology	
1. Identify major branches of biology.	B2b
2. Relate applications of biological principals to everyday living.	A, E1a
B. Discuss Scientific Methods	
1. State a problem and form an hypothesis.	A, B9a-c
2. Given a problem, construct a problem solving method.	A, B1-11
II. Energy and Matter	
A. Energy	
1. Define energy operationally.	B8a, D1c, D5b
2. List forms of energy and explain transfer from one form to another.	D1-14, C6d
3. Through an investigation, collect and record data and draw a conclusion.	A, B7c, B9a-c
B. Matter	
1. Demonstrate the characteristics of solids, liquids and gases.	B1a, C1b
2. Demonstrate the difference between chemical and physical changes.	B10b, C1d, C2d
3. Construct a diagram of an atom.	B11b, C2a, C2e, C5c
4. Compare covalent and ionic bonding.	C2d, C5c, C5e
5. Record the symbols for the 10 most common elements in the human body.	C2a, C5a, C5b, C5d
6. Distinguish between inorganic and organic compounds.	C2f, C5d
7. Demonstrate the characteristics of solutions, suspensions and colloids.	B8a, C1d, C4d
8. Demonstrate the presence of organic molecules by using chemical tests for proteins, carbohydrates and fats.	B10b-c, C2f
9. Describe the activity of enzymes in living cells.	C2f, C5d, E1e, E4b, E4c, E6a
III. Cells	
A. Microscope	
1. Identify the basic types of microscopes.	B1a, B2b
2. Demonstrate the proper care, handling and storage of a microscope.	B1a
3. Identify and discuss the function of the parts of the microscope.	B1a, B8a
4. Prepare a wet mount slide.	B10b, E6a
5. Determine the magnification of a microscope.	B1c, B5a
6. Calculate the diameter of the field in microns.	B1c, B5a
7. Describe the characteristics and structure of an organism from a prepared slide.	B1a, B10b, E6a
B. Structure	
1. State contributions of Robert Hooke, Matthias Schleiden, Theodore Schwann.	E2a, E2b, E2c
2. Prepare wet mount slides of animal and plant cells and compare.	B1a, B2a, B2b, E6b
3. Diagram and label the parts of a typical cell.	B11b, E2b
4. Describe briefly the function of each part of the cell.	E2b, E2c, E6c
5. Explain the cell theory.	E2a, E2c, E6c
6. Compare procaryotic and eucaryotic cells.	E2c, E6c

Course Objective	Essential Skills Objective
C. Function	
1. Define homeostasis.	E2a, E4c, E5a-c
2. Demonstrate how homeostasis applies at the cell level.	B10a, B10b, B11b, E5a
3. Demonstrate and explain osmosis.	B10a, B11b, E5a
4. Compare active transport and pinocytosis.	B11b, E5a
5. Predict direction of water flow, in osmosis, when concentrations are inside and outside of cell	A, B1b, B10a-c, B4b, E5a-d
6. Demonstrate the production of carbon dioxide during cell respiration.	B10a-c, C5d, E4a, E4b, E6c
7. Order the stages of cell respiration and explain the function of ATP.	E1e, E4a, E4b, E6b, E6c
8. Compare cell respiration and photosynthesis.	B2b, E1e, E4a, E6b-d
9. State Watson's and Crick's contribution to cytology.	E2a-e
10. Diagram and label a Watson-Crick Model of DNA.	E2a-e
11. Describe the role of DNA, the ribosome, messenger RNA, transfer RNA and amino acids in protein synthesis.	E1e, E2a-e, E4a-c
D. Cell Division	
1. Order and describe the phases of mitosis.	B11b, E1e, E2a-e, E4a
2. Order and describe the phases of meiosis.	B11b, E1e, E2a-e, E4a
3. Compare mitosis and meiosis.	B11b, E1e, E2a-e, E4a
IV. Genetics	
A. Describe Gregor Mendel's experiments with garden peas.	B11b, E1a, E2e-g
1. Discuss Mendel's three basic genetic principals.	B4a, E1a, E2e-g
2. Discuss elementary probability theory and Mendel's results.	A, B4a-b, B7a, B11b, E2e-g
3. Calculate monohybrid and dihybrid crosses using Punnett squares. Give results in ratios.	A, E2e-g, E4a
B. Define phenotype, genotype, homozygous, heterozygous and alleles.	E2d-g
1. Compare dominant, recessive, incomplete and codominance.	E2d-g
2. Explain sex determination.	E2d-g
3. Demonstrate the laws of segregation and independent assortment.	E2d-g
4. Use Chi-square to determine the significance of differences between observed and expected frequencies.	A, B1b, B3b, B4a
5. Describe crossover and linkage.	E2b-g
6. Explain chromosomal nondisjunction.	E2b-g
C. Discuss the contributions of Sutton, Morgan, Beadle and Tatum.	B11b, E2f, E2g
1. Explain mutations and causes of mutations.	E2d, E2e, E4a, E6a
2. Define population genetics.	E2d, E2e-f, E4a. E6a
3. From a population (class) compute frequencies of some genetic characteristics (PTC responses, dimples, attached and nonattached ear lobes, tongue rolling, etc.).	A, E2f, E4a, E6a
4. Explain the term genetic pool.	E2e-f, E4b
D. Name several syndromes caused by nondisjunction of sex chromosomes.	E1a, E2e-f

Course Objective	Essential Skills Objective
1. Describe genetic diseases (sickle-cell anemia, PKU, Tay Sachs) and their causes.	E1a, E2e-f
E. Conduct blood typing activities and demonstrate graphically the inheritance of blood type.	A, B1b, B6b, E1b
F. Debate the Nature/Nuture issue.	A, B3a, B4b, B9b, E1a, E2g, E3a-e.
G. Debate the use of bioengineering as a means of improving human life.	A, B3a, B9b, B11a, E1a, E3c, E4a
H. Explain how plant and animal varieties can be improved by applying genetic principles.	A, E1a, E1c, E3b, E4a
V. Historical Variation	
A. Theories of Evolution	
1. Explain the main ideas in Lamarck's theory.	B3a-b, E3a, E6a
2. Relate Lamarck's theory to the main ideas of Darwin's theory.	B3a-b, E3a, E6a
3. State the main ideas of the mutation theory.	E2e-g, E6a
B. Discuss evidence of common ancestry among animals.	E2e-g, E6a
C. Name the main geological eras and the dominant organisms of each geological period.	E1a-c, E6a
D. Compare natural and artificial selection.	E2a, E2e, E6a
VI. Organization of Living Things	
A. Nomenclature	
1. Describe the contributions of Carolus Linnaeus.	B2a-c, E6a-d
2. Use the binomial method of nomenclature to identify organisms.	B2a-c
3. Order the classification hierarchy of categories.	B2a-c, E6c
4. Discuss the basis of classification systems.	B2a-c, E6a-d
5. Use a classification key to identify an organism.	A, B2a-c, E6a-d
B. Microorganisms	
1. Explain the germ theory.	B3a-b, E1a, E3c
2. List Koch's four postulates on germ theory.	B3a-b, E1a, E1c
3. Describe the discovery of penicillin and relate to the scientific method.	A, B1-11, E1a, E1d
4. Describe how viruses were discovered.	E1a, E1d
5. Explain the chemical make-up of viruses.	E1a, E1b
6. Divide viruses into three groups/classes and explain.	B1b, B2a, E1a
7. Prepare and present a report on a specific virus.	B6a, B7a, B6c, E1a

Course Objective	Essential Skills Objective
C. Protista	
1. Schizomycetes	
a. Classify bacteria according to shape.	B2b, E2c
b. List conditions needed for growth.	B1a, E3a
c. Using sterile techniques, prepare a bacterial culture.	B1a, B10b, E2b, E6b
d. Apply a staining process to bacterial slides.	B1a, B10b, E2b, E6b
e. Compare a heterotroph to an autotroph.	B2b, E2b
f. Discuss dormancy and spore formation.	B1b, E2b
2. Cyanophyta	
a. From direct observation, describe the characteristics of varieties of algae.	B1a, E1b
b. Compare different species.	B1a, B2b, E1b
3. Myxomycophyta	
a. Describe the life cycle of the slime mold.	B1a, E1b, E1e
4. Eumycophyta	
a. Compare species of molds.	B1a, B2b, E1b
b. Explain the role of molds in the decomposition process.	A, E1a, E1d
5. Protozoa	
a. List the characteristics of the four phyla of protozoans.	B2a
b. Identify nine life processes in the Amoeba, Euglena and Paramecium.	B2a, E1a, E1e
6. Name at least six ways in which Protista are beneficial.	E1a, E1d, E3c
7. Name the symptoms, diseases and treatment caused by one protist in each division of Protista.	E1a, E1d
8. Explain the difficulty in classifying the protists.	B2c, E1a, E6a
VII. Invertebrates	
A. Porifera	
1. From observation, relate structure of sponges to function.	B1a-c, E6b, E6c
2. Name three typical sponges.	B1a, B2b, E6b
3. Describe the support system of sponges.	E1b, E6b
4. Name three ways in which sponges are beneficial to people.	E1a, E1c, E3c
B. Coelenterates	
1. Identify four basic characteristics of coelenterates.	B1a, E6b
2. From observation of a hydra, describe five life functions of coelenterates.	B1a, E1b, E6b, E6c
3. Name three coelenterates and tell how people are affected by them.	E1a, E1d, E3c
C. Platyhelminthes	
1. From observing planaria, list three general characteristics of flatworms.	B1a, E6b
2. Describe the life functions of flatworms.	B1a, E1b, E6b-c
3. Identify several varieties and their effects on humans.	E1a, E1d, E3c
4. Demonstrate regeneration.	B10b, E4a, E6b
D. Nematoda	
1. List seven basic characteristics of nematodes.	B1a, E6b
2. Distinguish between parasitic and nonparastic nematodes.	E1a, E1d, E3c
3. Identify five common types.	B1a, B1b, E3c
4. Explain how nematodes affect plants and animals.	B1a, E1a, E1d, E3c

Course Objective	Essential Skills Objective
E. Annelida	
1. From observing an earthworm describe the external anatomy of "true worms".	B1a, E6b
2. Compare the circulatory and digestive systems to those of the flatworms.	B1a, B2b, E6a
3. Compare terrestrial and marine varieties.	B1b, E6c
F. Mollusca	
1. List general characteristics of mollusks.	B1a, E6b
2. Compare classes: symmetry, shells, habitats and life cycles.	B2a, E1e
3. Enumerate ways in which mollusks are destructive.	B1a, E1a, E3c
4. Develop a list of mollusks useful to people.	E1a, E1d, E3c
G. Echinodermata	
1. Name the major characteristics of echinoderms.	B1a-b, E6b
2. Compare radial and bilateral symmetry.	E1a, E1b
3. Describe variations found among echinoderms.	E6b-c
4. Name 5 common varieties.	B1a, E3c
5. Determine the economic importance.	E1a, E3c
H. Arthropoda	
1. Name and give examples of each class of arthropods.	B1a, B1b, E6b
2. Develop a chart to compare classes of Arthropoda as exhibited by defensive and offensive structures, life cycles, antennae and body structure.	B1a-c, E1e, E6c
3. Discuss food getting and respiration.	E6b-c
4. Explain the nutritional value of crustaceans.	E1a, E3c
5. State advantages and disadvantages of exoskeletons.	A, E6b-c
6. Describe complete metamorphosis.	E1e, E4a-c, E6b
7. Discuss the importance of insects to people.	E1a, E1c, E1d, E3c
8. State how pheromones are used by social insects.	E1e, E6c
9. Explain the caste in a honeybee society and give significance of bee and wagging dances.	E1a, E1d, E4a-c
VIII. Chordata	
A. Hemichordata	
1. List characteristics.	B1b, E6b
2. Name a typical variety.	B1b
B. Cephalochordata	
1. List characteristics.	B1b, E6b
2. Name a typical representative of cephalochordates.	B1b
C. Urochordata	
1. List characteristics.	B1b, E6b
2. Identify a typical urochordate.	B1b
D. Vertebrata	
1. List seven classes of vertebrates and typical representatives of each.	B1a, B1b, E6b
2. Name the specialized systems found in vertebrates.	B1b, E1b, E6c
3. List three major characteristics of sharks, skates and rays.	E6c
4. Identify internal and external organs of fish.	E6c
a. Describe role of gills in respiration.	E6c, E6d
b. Discuss the role of the heart in a closed circulatory system.	E6c, E6d
c. Explain the optic lobe of the brain and sight.	E6b-d

Course Objective	Essential Skills Objective
5. Describe spawning habits of fish.	E1a, E1e, E4a
6. List five ways in which fish benefit people.	E1a, E3c
7. List the orders of the class amphibia.	B1a-b, E6b
a. Compare tadpoles and adult frogs.	E1a, E6a-c
b. Differentiate between toads and frogs.	B1b, E1a
c. Explain how amphibians are adapted for land and in water habitats.	E6b-c
d. Identify external features of the frog.	B1a, E6c
e. Describe adult heart of a frog.	E6b, E6c
f. Explain the fertilization process of a frog.	E1b, E4a, E6c
g. Distinguish between hibernation and estivation.	E4a, E5a
8. List four orders of the class reptilia and name typical representatives of each.	B1a-c, E6b
a. Relate internal organs of snakes to body functions.	B1d, E6c
b. Differentiate between oviparous and ovoviparous snakes.	E6b-c
c. Name four families of poisonous snakes.	B1b, E3c, E6b
d. Discuss three ways snakes obtain food.	E1a, E6b-c
e. Discuss adaptations of lizards to various environments.	E3a, E6b-c
f. From direct observation, describe six external structural adaptations of turtles.	B1a, E1b, E6b-d
g. Discuss importance of reptiles to people.	E1a, E3c-e
9. Give three general characteristics of class aves.	B1a-b, E6b
a. Discuss the metabolic process in birds.	E1b, E6b-c
b. Distinguish between cold and warm bloodedness.	B1b, E6b
c. Describe a bird's heart.	E6b-c
d. Explain weight reduction adaptation in birds.	E6b-c
e. Identify the type of fertilization.	E4a, E6b-c
10. List eight characteristics of mammals.	B1a, E6b
a. Identify two orders of primative mammals and give examples.	B1b, E6a
b. Discuss characteristics of sixteen orders of placental mammals and give examples of each order.	B1a-c, E6a
c. Discuss tissue specialization.	E6a-c
d. Explain patterns of parental care in mammals.	E1a, E1e, E6c
11. Explain drives, instincts and reflexes in animals.	E2a, E4c, E6c
12. Demonstrate reflex responses.	E1b, E6b
13. Discuss societal relationships in ants, herds, packs, terrestrial control and pecking orders.	B1a, B7a, E1a, E1c, E4a
14. Discuss instincts in spawning, courtship, migration, hibernation and estivation.	E1a, E1c, E4a, E6a
15. Identify communication techniques, pheromones, echoes, bioluminescence, navigation and biological clock.	E1a, E4a, E6c
IX. Homo Sapiens	
A. Digestive System	
1. Define food.	D9a-b, E3d
2. Classify food substances and organic nutrients.	D9a-b, E3d
3. Measure the number of calories in a food sample.	A, B5a, B7a, D9a
4. Describe functions of the mouth and esophagus in digestion.	E1b, E4b, E6c
5. Show why starch must be digested.	B10b-c, E1b, E4d, E6b
6. Explain digestive processes which take place in the stomach.	E1b, E6b-c
7. Describe the role of the small intestine in digestion.	E1b, E6b-c
8. a. Name the roles of the liver and gall bladder.	E6b-c
b. List digestive enzymes and indicate products of their reaction.	E6b-c
c. Describe how absorption takes place.	E1b, E5a, E6b-c
9. Debate food fads, fact and fiction.	E3c-d

Course Objective	Essential Skills Objective
B. Transport	
1. Diagram and label part of the circulatory system.	B11b, E1b, E6b
2. Compute the pulse rate from a series of readings.	B5a, E4d
3. Identify locations of heart valves and their functions.	E1b, E6b-c
4. Trace the flow of blood into and out of the heart.	E6b-c
5. Describe plasma.	E6b
6. Describe three types of blood cells and their functions.	B1a, E6b-c
7. Describe the role of the lymphatic system.	E1b, E6b-c
8. Name various organic and inorganic substances carried by the blood.	C5d, D9a, E1b
C. Respiration	
1. Name organs involved in respiration and the function of each.	B11b, E1b, E6c
2. Describe breathing.	E1b, E6b-c
3. Measure lung capacity.	B5a-b, E3c, E4d, E6c
4. Distinguish between breathing and respiration.	C1i, E1e, E6c
5. Describe carbon dioxide/oxygen exchange in the lung.	C1i, E1e, E6c
6. Measure the amount of exhaled CO_2.	B5a-b, E3c, E4d
7. Diagram the stages in the citric acid cycle.	B11b, C1i, E1e
D. Muscular System	
1. Identify three main types of muscles.	B11b, E6b
2. Label the parts of a muscle on a diagram.	B11b, E1b, E6b
3. Describe muscle function.	B1a, E6b-c
4. Name and locate common muscles.	B1a, B11b, E6b
E. Skeletal System	
1. Name five basic functions of the skeletal system.	B1a, E1b, E6b
2. Relate three types of joints to their functions.	B1a, E1b, E6b-c
3. Locate cartilage areas in children and adults.	B1a-b, B11b, E6b
4. Label the major parts of a diagram of a skeleton.	B1a, B11b, E6c
F. Excretory System	
1. Describe the lung as an organ of excretion.	E1b, E6c
2. Identify the parts of a kidney and name the function of each.	B11b, E6b-c
3. Relate the skin and liver to excretory processes.	B11b, E6b-c
G. Nervous System	
1. Discuss two roles of the nervous system.	E1b, E6b
2. Compare sympathetic and parasympathetic nerves.	E1b, E6c
3. Diagram and label parts of the nervous system.	B11b, E6b-c
4. Explain graphically the functioning of a neuron.	B11b, E2a-b
5. Describe the regions of the brain and the functions of each.	B11b, E1b, E6b-c
6. Differentiate between inborn and acquired behavior.	E1b, E2e, E3d
7. Discuss perception, learning and intelligence.	E1b, E2e, E3d
8. Develop a report on the effects of drugs on behavior.	A, B1a, B3a, E1b, E3c-d
9. Explain effects of alcohol on human body and behavior.	A, B1a, B3a, E1b, E3c-d
10. Discuss how smoking affects the human body.	A, B1a, B3a, E1b, E3c-d
11. Discuss receptors found in the skin and explain reactions to stimuli.	E1b, E6b-c
12. Relate the senses of seeing and hearing to the nervous system.	D12e, E1b, E6b-c
13. Diagram and label the eye and the ear.	D12e, E1b, E6b-c
14. Locate the taste receptors on the tongue.	B1a, E1b, E6b-c

Course Objective	Essential Skills Objective
H. Endocrine System	
1. Construct a chart of endocrine glands showing where they are located and hormones produced.	B2a, B6b, E1b, E6b-c
2. Describe the effects of hypo- and hypersecretions of glands.	E1b, E6b-c
I. Reproduction and Development	
1. Identify the male reproductive organs.	B11b, E1b, E6b-c
2. Name the male hormones and describe their effects.	E1b, E6b-c
3. Identify the female reproductive organs.	B11b, E1b, E6b-c
4. Discuss female hormones and their effects.	E1b, E6b-c
5. Order and discuss the menstrual cycle.	E1b, E1e, E4a, E6b
6. Explain fertilization including where the sperm and egg unite.	E1b, E2a, E4a
7. Outline growth stages from conception to birth.	B11b, E4a, E6b-c
8. Describe embryonic membranes and their functions.	B11b, E4a, E6b-c
J. Social Diseases	
1. Gonorrhea	
a. Describe symptoms.	E1a, E2a, E3c
b. Discuss treatment and resistance to treatment.	E1a, E2a, E3c-d
2. Syphilis	
a. Describe the various stages.	E1a, E2a, E3c-d
b. Explain transmission and treatment.	E1a, E2a, E3c-d
c. Describe what happens if syphilis is untreated.	E1a, E2a, E3c-d
3. Herpes	
a. Describe the transmission and symptoms of the disease.	E1a, E2a, E3c-d
b. Discuss treatment.	E1a, E2a, E3c-d
X. Plant Kingdom	
1. From direct observation, describe the structure of mosses.	B1a, E1b, E6b
2. Diagram and explain the life cycle and the meaning of "alternation of generation".	B11b, E1b, E6b-c
3. Compare mosses and liverworts.	B1a, B2a, E6b-c
4. Describe two characteristics of bryophytes that limit their size.	E4a, E6c
5. Discuss the economic importance of sphagnum moss.	E1a, E3c
B. Tracheophytes	
1. Ferns	
a. Compare the life cycle of a fern to the life cycle of a moss.	B1a, E6a, E6b
b. What advantages do ferns have over mosses?	B1a, E6b-c
2. Gymnosperms	
a. Identify the characteristics of the gymnosperms.	B1a, E1a-b
b. Define a seed plant.	E2a, E6a
c. Name five common conifers.	B2a, E2a
d. Describe the life cycle of the pine.	B1a, E1e, E6b
e. Discuss the economic and environmental value of conifers.	B3a, E1a, E1c, E3c

Course Objective	Essential Skills Objective
3. Angiosperms	
a. Monocots	
(1) Give the basic characteristics of monocots.	B2a, E6a, E6b
(2) Name some common monocots and their families.	B2b, E6a, E6b
(3) Describe some uses of monocots.	E1a, E3c
b. Dicotyledons	
(1) Give the main characteristics of dicots.	B2a, E6a, E6b
(2) Name some typical dicots and their families.	B2b, E6a, E6b
(3) Explain the economic importance of dicots.	E1a, E3c
(4) Compare structures of monocot and dicot stems	A, B10b, E6b
C. Roots	
1. Diagram and label the parts of a typical root.	B11b, E2a
2. Distinguish between tap roots and fibrous roots.	B2a, E6b
3. Discuss anchorage, absorption and storage in roots.	E2a, E6b, E6c
4. Identify basic types of roots.	B2a, E6b
5. Explain the functions of various root tissues.	E2a-b, E6c
6. Determine how roots grow.	A, B1a, B10b, E4b
D. Stems	
1. Distinguish between herbaceous and woody stems.	B2a, E6c
2. Identify the tissues within each kind of stem.	B2a, E2a, E6c
3. Discuss conduction.	E2a, E6b-c
4. Distinguish between phloem and xylem.	B2a, E6c
5. Describe the differences between stems of monocots and dicots.	B2a, E6b-c
6. Name and distinguish between five kinds of modified stems.	B2a-b, E2a, E4b
7. Distinguish between terminal and axillary buds.	B2b, E6b-c
E. Leaves	
1. Identify from direct observation the internal structures of a leaf.	B1a, B2a, B11b, E6b-c
2. Identify the margin, venation, apex, base and shape in some common leaves.	B1a, B11b, E6c
3. Demonstrate water loss through transpiration.	A, B10b, E1e, E3e, E6c
4. Demonstrate photosynthesis.	A, B10b, E1e, E3e
5. Identify 10 trees by leaf characteristics.	B2a-c, E3e
6. Measure the growth rate of plant organs.	A, B5b, B10b, E4b
F. Flowers	
1. Dissect and identify the parts and functions of a typical flower.	A, B1a, E6b-c
2. Explain the function of a flower.	E2a, E6c
3. Classify selected flowers as perfect, imperfect, complete, incomplete.	A, B1a, B2b, E6b-c
4. Order the fertilization process from pollen grain to double fertilization.	E2e, E2g, E6b-c
5. Compare self-pollination and cross pollination.	E2e, E2g, E6b-c
6. Describe germination of a pollen grain.	B1a, E4b
G. Fruits and Seeds	
1. Compare the parts of dicotyledon and monocotyledon seeds.	B1a, B2b, E6b
2. Demonstrate differences in growth of dicot and monocot seedlings.	B1a, B2a, B10b, E4b
3. Explain the formation of fruit.	E4b, E6b-c
4. Show the floral parts still evident in a ripened fruit.	B1a, E4b
5. Classify plants as monocots or dicots according to leaf venation, vascular bundle arrangement and flower parts.	B1a, B2a-c, E3e

Course Objective	Essential Skills Objective
H. Plant Response	
1. Explain plant hormones.	E1b, E4b
2. Demonstrate the effect of light on plant growth.	A, B4a, B10b, E4c
3. Relate auxins to phototropism.	E4b, E6c
4. Demonstrate the meaning of apical dominance.	A, B10b, E2a, E4b
5. Relate gibberillins to plant growth.	E1b, E4b
6. Explain photoperiodism.	E1e, E6b
7. Demonstrate the effect of gravity on plant growth.	A, B4a, B10b, E4c
XI. Ecology	
A. Biomes	
1. Name nine major biomes and give locations for each.	B1a, C3c, E1a, E3e, E4b
2. Identify typical flora and fauna in each type of biome.	B1a-b, E1a, E3e, E4b
3. On a map of Georgia locate five physiographic regions.	B1a, B7a, E1a, E3e, E4b
4. Identify typical flora and fauna in each Georgia region.	B7a, E1a, E3e, E3c, E4b
B. Ecosystems	
1. Define biosphere and ecosystem.	B8a, E1a, E1d, E3a
2. Distinguish between the biotic and abiotic factors in an ecosystem.	B8a, E1a, E3a, E3e
3. Illustrate and explain the water cycle and how plants and animals are involved.	B11b, C1i, C3i, E1a, E1e, E3a, E3e, E5a
4. Explain the carbon-oxygen cycle.	B11b, C1i, C5d, E1a, E1e, E3a, E3e, E5a
5. Discuss a balanced aquarium.	A, B11b, E1a, E1c
6. Demonstrate CO_2 production by plants and animals.	A, B10c, E1e, E3e
7. Demonstrate the interaction of plants and animals in the CO_2 cycle.	A, B10c, E1a, E1e, E3e
8. Explain the nitrogen cycle.	B11b, E1a, E1e, E3a, E3e, E5a
C. Populations	
1. Distinguish between individuals and populations.	B2b, E1a
2. Explain the S-curve population graph.	B6b, B7a, E1a, E1c, E3b
3. Describe the four environmental factors which determine density of a population.	B2b, E1a, E3e
4. Describe ways in which a population affects its environment.	E3b, E3c-e, E4a-c
5. Propose a program to solve the problem of food deficiencies due to overpopulation.	A, B9a-c, E3b, E4a-c
D. Food Chains	
1. Define habitat and niche.	B2b, E1a, E3a-b
2. Diagram and describe a food chain web in an ecosystem.	B11b, E1a, E1c, E3a-e
3. Diagram an ecological pyramid and explain energy loss.	B11b, D8a, D9b, E1a, E3a-e
4. Trace energy to its original source.	A, C3b, D9b, E1e, E3e, E4c
5. Describe and give examples of symbiosis, parasitism, commensalism and photocooperation.	E1a, E1d, E3e
E. Interdependence	
1. Identify five kinds of ecological relationships.	E1a, E1d, E1e, E4a, E4b
2. Demonstrate changes in an ecosystem.	A, B1a, B10c, E4a-c
3. Identify interdependencies of organisms in a given ecosystem.	A, E1a-e, E3a-c
4. Identify ways in which people affect ecosystems.	A, E1a, E1d, E3a-c
5. Explain the role of homeostasis in the maintenance of life.	A, E1a-e, E4a-c, E5a-d
6. Identify problems in an ecosystem.	A, B1b, B9a-c, E3a-e

Course Objective	Essential Skills Objective
7. Conduct an ecological survey. Interpret results.	A, B6a-b, B7a, E3a-e
8. Propose solutions to ecological problems.	A, B3a-b, B4a, B9a-c, E3a-e

Course Outline — Chemistry

Course Objective	Essential Skills Objective
I. The fundamental units and theories of the science of chemistry	
A. Chemistry as a science	
1. Definition of science	B
2. Definition of chemistry	B
3. Differences between chemistry, physics and biology	B
4. Difference between an observation and an interpretation	
5. Difference between accuracy and precision	
6. Measurements have three parts—coefficient, units and uncertainty	B5
7. The use and limitations of models in explanations	B11
8. The metric units of length, area, volume, mass, force and energy are used in chemistry	C1, C2, C4
9. The difference between an operational and conceptual definition	B8a, b
B. The units of chemistry—atoms, molecules, moles and atomic/molecular weight.	
1. The three definitions of the mole	B5e
2. The difference between atoms and molecules	
3. The calculation of atomic and molecular weight	B5e
4. The use of dimensional analysis (factor unit label method) to convert quantities given in one definition of the mole to any other	B5e, B12
5. Chemical symbols, formulas and equations	
C. The atomic theory	
1. A simple model of the atom	B2a
2. The location of electrons, protons and neutrons in the atom	B2e
3. The difference between elements and compounds	B5a
4. Nomenclature of simple compounds	
5. Reading chemical equations in mole units.	B5e
6. Balancing chemical equations	
7. Using dimensional analysis and the definitions of the mole to solve stoichiometric problems	B12
8. Evidence for the atomic theory	
i. The law of simple multiple proportions	
ii. The law of definite composition	
D. The kinetic molecular theory and gas laws	
1. The combining volumes of gases	
2. Avogadro's hypothesis	
3. The definition and units of pressure	
4. Atmospheric pressure	
5. Pressure and volume of gas are inversely related ($PV = k$)	
6. The difference between an absolute and relative measurement	
7. The definition of temperature	C14b, c
8. The relationship between Celsius and Fahrenheit temperatures	C14b
9. The absolute temperature scale	C14b
10. The volume and pressure of a gas are directly proportional to the absolute temperature ($V = kT$ and $P = kT$)	
11. The difference between heat and temperature	C14d
12. Each gas in a mixture contributes pressure independently of the others	

Course Objective	Essential Skills Objective
13. The concept of an ideal gas	
14. Reasons real gases are nonideal	
i. Real molecules do have volume	
ii. Weak attractive forces do exist between molecules	
15. The ideal gas law is a statement of energy equivalency between the atomic kinetic level and the macroscopic level (PV = nRT)	B11b
E. Liquids and solids—condensed phases of matter	
1. The nonideality of gases causes liquefaction	
2. The atomic model of a solid can be used to explain its properties	B1i, B2a
3. The atomic model of a liquid can be used to explain its properties	B1i, B2a
4. Boiling point is defined in terms of vapor pressure and external pressure	
5. The relationships between vapor pressure, temperature, strength of intermolecular forces, heat of vaporization and boiling point	
6. Solutions	
i. Know terms solute, solvent saturated, unsaturated, electrolyte, ions and ionization	B1d
ii. Be able to calculate molality and molarity	
iii. Predict change in vapor pressure	
7. Equilibrium models of phase changes	D5a, c
II. Reaction chemistry	
A. Energy changes in chemical reactions	B1i
1. Energy is conserved in chemical reactions	C9b
2. All chemical substances contain a certain amount of chemical energy or enthalpy	C9c
3. The heat of reaction indicates the chemical energy difference between the reactants and the products	C14a
4. Reactions with negative heats of reaction are exothermic: positive heats of reaction are endothermic	
5. Energy terms may be written in balanced chemical equations	
6. Entropy is a measure of disorder in a system	
B. Rates of reaction	
1. Units and meaning of a rate of reaction	
2. The distribution of kinetic energy for a sample of molecules	C14b, c
3. The concept of reaction mechanism	
4. The concept of activation energy	
5. Energy charts of reactions	
6. The mechanism of catalytic change of reaction rate	
C. Equilibrium in chemical reactions	
1. The paradox of equilibrium is how can continuous change produce a system which is not changing: the resolution to the paradox is that two offsetting microscopic changes are occurring	D5a, c
2. The definition of the equilibrium constant as a ratio of forward and reverse rate constants	D5d
3. The definition of the equilibrium constant as a ratio of amount of products to reactants	D5d
4. Neither the balanced chemical equation nor the rate of reaction can be used to predict the equilibrium constant	D5d

Course Objective	Essential Skills Objective
5. Le Chatelier's principle helps predict the effects of changes in the equilibrium condition	
6. Temperature changes do affect the equilibrium constant	
7. Equilibrium may also be defined as a balance between the tendencies to minimize enthalpy and maximize entropy	D5a, d
D. Solubility equilibrium and precipitation reactions	
1. Precipitates may be predicted by using solubility tables	D5d
2. Equilibrium concentrations of species present may be calculated by using the solubility product constant	B7a
3. Substances may be quantitatively and qualitatively analyzed by using solubility data	
E. Acid base reactions	B4d, e
1. Operational definitions of an acid	
i. Phenolpthalein colorless	
ii. Litmus red	
iii. Tastes sour	
iv. Electrolytes	
v. React with Zn giving H2	
vi. Nonmetal oxides	
2. Operational definitions of a base	
i. Phenolpthalein red	
ii. Litmus blue	
iii. Tastes bitter	
iv. Electrolytes	
v. Feels slippery	
vi. Metal oxides	
3. Conceptual definitions of an acid	
i. Forms H+ in water	
ii. Proton donor	
iii. Electron pair acceptor	
4. Conceptual definitions of a base	
i. Forms OH- in water	
ii. Proton acceptor	
iii. Electron pair donor	
5. Dissociation of weak acids and bases	
i. Acid dissociation constant	
ii. Kw	
6. Calculating pH	B4b
7. Titration problems	
F. Oxidation-reduction reactions	
1. Definitions of oxidation and reduction	
2. Oxidation numbers	
3. Balancing equations using oxidation numbers	
4. Batteries and electrodes	C9c
5. Electrolysis	C9e
III. Better models of atomic and molecular structure	B2e
A. Atoms and the periodic table	
1. Atomic number, atomic weight, atomic mass number, isotopes	
2. Calculation of the number of neutrons given the atomic mass number	
3. Radioactivity	B13d
i. Alpha decay	
ii. Beta decay	

Course Objective	Essential Skills Objective
4. Elementary electrostatics	C10a, b
5. Mechanism of ion formation	
6. Ionization energy	
7. Periodicity of ionization energy	B5b
8. Periodicity of atomic size	B5b
9. Periodicity of chemical properties	B5b
10. Chemical families	B5b, c
i. Alkali metals	
ii. Alkaline earths	
iii. Halogens	
iv. Noble gases	B5e
11. Shell model of atoms	
12. Chemical properties are related to the electron population of the outer shell	
13. The periodic table can be used to predict reaction ratios in compounds	
14. Chemical bonds can be formed by the transfer or sharing of outer shell electrons if these processes leave filled shells	
B. Electromagnetic radiation provides a window into atomic structure	C11
1. The electromagnetic radiation spectrum	C11h
2. The particle-wave duality of light	C11b
3. Wavelength times frequency equals the speed of wave propagation	
4. Energy equals frequency times Planck's constant	
5. Quantum theory of energy	
6. Bohr's quantum model of electron orbits	
7. Failure of the planetary model of atomic structure	
8. The difference between an orbit and an orbital for an electron	
9. The orbital model explains the observed spectrum of hydrogen	
10. Discrete spectral lines represent discrete energy differences between orbitals in atoms	C11e
11. Light may be emitted when electrons move to a lower orbital and absorbed when electrons move to a higher one	
12. Periodic properties can be explained by shell and orbital filling rules	
C. Covalent bonding	B2d
1. Nature of covalent bond	
2. Electron dot models of covalent bonding in molecules	B11b
3. Polar bonds	
4. Molecular dipoles	
i. Van der Waals forces	B4c
ii. Hydrogen bonding	
iii. Water molecule	B4b
5. Structural formulas and stick models of simple molecules	B11b
6. Multiple bonds	
7. Structural isomerism	
8. Molecular orbital theory	
9. Allotropes of carbon and other network solids	
D. Ionic and metallic bonding	B2d
1. The nature of the ionic bond	B4d
2. Characteristics of ionic substances	B4d
3. The mechanism of conduction in ionic solutions and melts	
4. The nature of metallic bonding	B6c
5. The properties of metals	B6c

Course Objective	Essential Skills Objective
E. Organic chemistry	
1. The difference between empirical and molecular formulas	
2. The experimental determination of empirical formula	
3. The experimental determination of molecular formula	
4. Structure determines chemical properties	
5. Functional groups	B5d
i. Alkanes, alkenes, alkynes	
ii. Alcohols	
iii. Carboxylic acids	
iv. Ethers	
6. Simple nomenclature	

Course Outline — Physics

Course Objective	Essential Skills Objective
I. Data Manipulation	
A. Make accurate lab measurements.	B1c, B5a, B6a, D3b
B. Apply rules for significant digits during measurements and data correlation.	
C. Determine accuracy and precision of lab measurements.	A, B5b
D. Express inverse and direct proportionalities among data.	B3a, B7a
E. Identify graphs of inverse and direct proportionalities.	B7a
F. Evaluate proportionality constants.	A
G. Distinguish scalar and vector quantities.	B2b
H. Perform graphical vector manipulations.	A
I. Perform trigonometric vector manipulations.	A
II. Rectilinear Motion	
A. Define displacement, velocity and acceleration as vector quantities.	
B. Distinguish speed and velocity.	B2b
C. Mathematically relate displacement, velocity and acceleration.	
D. Calculate average and instantaneous velocities.	A
E. Use vector addition to determine resultant velocities.	A
F. Use vector math to determine component velocity vectors.	A
G. Experimentally measure displacement, velocity and acceleration.	B1c, B5a, B5b, B10b, D2
H. Determine velocity from graphs of acceleration.	B7a
I. Derive the basic motion equations.	
J. Apply motion equations in determination of initial velocity, final velocity, displacement, acceleration and time interval.	A
K. Describe acceleration of gravity.	D7a, D7b
L. Quantitatively describe "free fall."	D7a, D7b
M. State Newton's Three Laws of Motion.	D1a, D6a, D6b
N. Relate force, mass and acceleration.	D1a, D6a, D6b
O. Identify action and reaction.	D6a
III. Momentum	
A. Define momentum.	
B. Relate momentum and impulse.	
C. Distinguish elastic and inelastic collisions.	B2b
D. Apply Law of Conservation of Momentum in analyzing collisions.	A

Course Objective	Essential Skills Objective
IV. Universal Gravitation	
A. State the Law of Universal Gravitation.	D1a, D7a, D7c
B. Relate gravity and weight.	D1a, D7a-D7b
C. Mathematically apply the Law of Universal Gravitation in determining attraction between masses.	A, D1a, D7c, D7d
V. Force	
A. List characteristics of force.	D1a
B. Resolve trigonometrically force vectors.	A, D1a
C. Trigonometrically determine resultant force vectors.	A, D1a
D. Experimentally investigate forces involved in inclined plane systems.	A, B1c, B10b, D1a, D1b
E. Describe translational equilibrium.	E5a
F. Identify equilibrant force.	E5a, E5d
G. Mathematically analyze systems involving the equilibrant.	A, E5a
VI. Friction	
A. Investigate nature of friction.	B1c, B7a, B10b, D14F
B. Describe characteristics of friction.	
C. Evaluate coefficients of friction.	A
D. Analyze vector problems involving friction.	A, D14F
VII. Parallel Forces	
A. Identify center of gravity of objects.	
B. Define torque.	B8
C. Investigate conditions required for rotational equilibrium.	B1c, B7a, B10b, D1a, D1b, E5a, E5d
D. Use rotational equilibrium to analyze torque problems.	A, C6b, D1a, D1b, E5a
VIII. Projectile Motion	
A. Determine horizontal and vertical components of projectile motion.	A
B. Determine horizontal velocity and displacement for projectiles.	A
C. Determine vertical velocity, displacement and time of flight for projectiles.	A, D7d
D. Experimentally investigate actual projectile motion.	B1c, B7a, B10b, D2, D3b
IX. Circular Motion	
A. Describe uniform circular motion.	
B. Define centripetal acceleration.	B8
C. Relate centripetal acceleration to tangential velocity and radius of curvature.	
D. Experimentally investigate centripetal motion.	B1c, B7a, B10b
E. Describe the requirements for orbital flight.	D7b, D7d
F. Calculate required orbital velocity.	A, D7b, D7d

Course Objective	Essential Skills Objective
X. Rotary Motion	
A. Correlate linear motion with rotary motion.	
B. Relate mass, shape and rotational inertia.	
C. Derive rotary motion equations for determination of angular displacement, angular velocity, angular acceleration and time intervals.	
D. Describe gyroscope operation.	
E. Analyze mathematically rotary motion problems.	A
XI. Periodic Motion	
A. Describe periodic motion.	D6b
B. Describe simple harmonic motion.	D6b
C. Investigate pendulum motion.	B1c, B7a, B10b, D2
D. Use pendulum motion equation in analysis of period of the pendulum, length of the pendulum and gravitational acceleration.	A, D7b
XII. Work, Power and Energy	
A. Mathematically define "work".	B8, D4
B. Determine work involved in various systems.	A, D4
C. Relate power output to work done.	D4, D5a, D5b
D. Perform calculations involving work and power.	A, D4, D5a, D5b
E. Relate energy and work.	D5b
F. Distinguish potential and kinetic energies.	D6, D7
G. Calculate potential and kinetic energies.	A, D6, D7
H. Describe requirements of Laws of Conservation of Energy and Momentum.	D8
I. Experimentally investigate efficiencies of machines.	D8, D14f
J. Use Laws of Conservation of Energy and Momentum to analyze energy and momentum problems.	A, D8
K. Describe various energy forms.	D9a, D9c, D10i, D11a, D12d, D13, D14
XIII. Nature of Solids	
A. Distinguish adhesion and cohesion.	C1i
B. Use tensile strength to determine breaking point of materials.	C1i
C. Define elasticity.	B8, C1i
D. State and experimentally investigate Hooke's Law.	B1c, B7a, B10b, C1i
E. Relate stress and strain.	C1i
F. Use "Young's Modulus" and Hooke's Law to describe stretching of materials.	C1i

Course Objective	Essential Skills Objective
XIV. Nature of Liquids	
A. Describe surface tension.	C1a
B. Relate cohesion, adhesion and capillary action.	C1i
C. Describe melting process in terms of intermolecular attractive forces and energies.	C1i, C2d
XV. Nature of Gases	
A. Describe expansion, pressure and diffusion of gases.	C1f, C1i
B. Describe vaporization process in terms of intermolecular attractive forces and energies.	C1i
C. Explain equilibrium vapor pressure.	E5a, E5c
D. Mathematically relate temperature, volume and pressure of gases.	C1i
XVI. Thermal effects	
A. Distinguish thermal energy and heat.	D14
B. Distinguish temperature and heat.	D14b, D14d
C. Define and distinguish heat capacity and specific heat.	B8
D. Determine experimentally specific heats of materials.	B1c, B10b, D14b
E. Use specific heat in mathematical analysis of heat transfer problems.	A, D14e
F. Determine experimentally coefficients of linear expansion.	B1c, B10b, D14a, D14b
G. Use coefficients of linear and cubic expansion to solve expansion problems.	A
H. Relate thermal energy and phase changes.	C1i, D14a
XVII. Waves	
A. Distinguish longitudinal and transverse wave motion.	
B. Identify frequency, amplitude, period, wavelength and velocity of waves.	
C. Mathematically relate velocity, wavelength and frequency.	
D. Experimentally investigate reflection, refraction and diffraction of waves.	B1c, B7a, B10b
E. Relate reflectance of waves to impedance change in medium.	
F. Describe superpositioning of waves.	
G. Distinguish destructive and constructive interference.	
H. Investigate standing waves.	B1c, B10b
XVIII. Sound	
A. Describe variation of speed of sound with varying temperatures.	D12b
B. Describe dependance of speed of sound upon density of medium.	D12b
C. Calculate intensity and intensity levels of sound.	A, D12a
D. Describe range of audibility of the human ear.	D12a

Course Objective	Essential Skills Objective
E. Mathematically analyze the Doppler Effect.	
F. Determine Doppler frequency shifts.	
G. Define harmonics.	B8
H. Experimentally investigate the Laws of Strings.	B1c, B7a, B10b, D12e
I. Experimentally investigate resonance of sound waves.	B1c, B10b, B7a
J. Mathematically design resonance tubes.	A, D12e
XIX. Nature of Light	
A. Describe Newton's Particle Theory of Light.	
B. Discuss developments leading to acceptance of wave theory.	D10j, D11b
C. Identify components of electromagnetic spectrum.	D10j, D11h
D. State implications of the Photoelectric Effect.	
E. List failures of the wave theory of light.	
F. Describe the dual nature theory of light resulting from Planck's equation.	D10j, D11b, D11e, D11h
G. Apply DeBroglie's Matter Wave equation.	
H. Discuss X-ray production as a consequence of the inverse photoelectric effect.	
XX. Reflection of Light	
A. State properties of reflection of light.	D11c
B. Distinguish real and virtual images.	D11c
C. Experimentally investigate image production by plane, convex and concave mirrors.	B1c, B7a, B10b, D11c
D. Draw ray diagrams to locate images for plane, concave and convex mirrors.	D11c
E. Observe derivation of mirror equation.	
F. Use mirror equation to analyze convex and concave mirror operation.	A, D11c
XXI. Refraction of Light	
A. State laws of refraction.	D11c
B. Define index of refraction.	B8
C. State and apply Snell's Law as $N_a \mathrm{Sin} 0_a = N_b \mathrm{Sin} 0_b$	D11c
D. Experimentally investigate lens optics.	B1c, B7a, B10b, D11c
E. Draw ray diagrams to locate images for various lens types.	D11c
F. Apply lens equation to analyze lens systems.	A, D11c
G. Describe dispersion of white light into color spectrum.	D11c, D11f, D11g, D11h
XXII. Diffraction and Polarization	
A. Describe production of diffraction interference patterns.	
B. Mathematically analyze operation of diffraction grating.	A
C. Describe transverse nature of light wave disturbances.	

Course Objective	Essential Skills Objective
D. Discuss requirements for polarization of light rays.	D11c
E. Experimentally investigate polarization phenomena.	B1c, B10b
XXIII. Electrostatics	
A. Apply Coulomb's Law.	A, D10a, D10b
B. Experimentally plot electric fields.	B1c, B10b, D10b
C. Define potential difference.	
D. Describe distribution of charges on conductors.	
E. Define capacitance.	
F. Determine combined capacitance of several capacitors.	
XXIV. Electricity	
A. Relate current, charge and time.	
B. Experimentally determine the relationship among current, potential difference and resistance to current flow in a circuit.	B1c, B7a, B10b, D10e, D10f-g
C. State and apply Ohm's Law.	A, D10g
D. Apply Kirchhoff's Law to series and parallel circuits.	A, D10g
E. Evaluate work and power in electric circuits.	A, D10h
XXV. Magnetism	
A. State Coulomb's Law for Magnetism.	D10c
B. Describe the domain theory of magnetism.	D10c
C. Discuss relationship of current flow to magnetic field generation.	
D. Describe operation of generators, motors and the transformer.	
XXVI. Alternating Current Circuits	
A. Define inductive and capacitive reactance.	D10h
B. Discuss operation of L, R, C circuits.	
C. Describe conditions necessary for resonance.	
XXVII. Electronic Components	
A. Observe and describe operation of vacuum tubes, transistors, diodes, the cathode ray tube and integrated circuits.	D10g
B. Observe use of components in amplifiers, radios, etc.	
XXVIII. Nuclear Physics	
A. Describe properties of the proton, neutron and electron.	D13a
B. Describe factors affecting nuclear stability.	D13a
C. Describe processes involved in radioactive decay.	D13d
D. Contrast fission and fusion.	D13b
E. Discuss modern applications of nuclear energy.	C6d
F. Discuss methods of radiation detection.	D13d
G. Become aware of modern nuclear particle research.	

Course Outline — Physical Science

Course Objective	Essential Skills Objective
I. Defining science	
A. Explain the differences between	A
1. Science as process and science as fact	
2. Science and technology	C6
3. Science and math	
4. Science and philosophy	
B. The processes of science	
1. Make observations	B8a, b; B9a; C1a;
a. Explain the difference between observations and interpretations	B1a, b; B6a; B3a
b. Use all five senses to observe	
2. Make measurements	B1c, B5a. b
a. Use the metric system	
b. Identify three parts of a measurement coefficient, units, uncertainty	B10d B10d
c. Use dimensional analysis (unit analysis or factor label method)	A
d. Discuss error and its sources	
i. Uncertainty, mathematical, logical bias (randomly distributed)	
ii. Human (biased)	
iii. Instrument (biased)	
iv. Procedural (biased)	
3. Search for regularities in observations and measurements	B7a, b; B9b
a. Use graphs to display different types of mathematic relationships	B6b
i. Independent variable vs. constant	
ii. Direct proportionality	
iii. Inverse proportionality	
iv. Exponential	
b. Cause and effect	
c. Models	B11a, b
d. Classification schemes	B2a, b, c
i. External similarities	B7a
ii. Functional similarities	
iii. Similarity of origin	
iv. Other methods	
4. Make statement of regularity from data (form hypothesis)	B3a, b, B4a; B9c
5. Design experiments to test a hypothesis	B4b; B10a; B10c
a. Identify important variables	
b. Limit variables in the system to two by holding others constant	B10c
c. Identify the independent variable, control it, and measure it	B10c
d. Identify the dependent variable and measure it as a function of the independent variable	
e. Communicate the results	
6. Identify proven hypothesis as confirming or contradicting existing higher level truths of science such as laws or theories	B6a, b

Course Objective	Essential Skills Objective
II. Describing and explaining the properties of different types of matter	
A. Observations	
1. Explain how one could observe the differences between	
i. Matter and energy	C5a
ii. Elements, compounds and mixtures	C1a
iii. Solids, liquids and gases	C1b; C2b, c
iv. Physical and chemical changes	C1c; D9
v. Acids and bases	C4e; C4f
vi. Metals and non-metals	C5b; C6c
vii. Hydrogen, nitrogen, oxygen and carbon dioxide gases	C5d
viii. Soluble and insoluble substances	C4d
ix. Mass, weight, density	
B. Atomic theory can be used to explain these observations	C2a
1. Identify atoms or molecules as the basic building blocks of matter	C2a; C2e
2. Draw a model of the structure of an atom	C2e
3. Discuss the properties of electrons, protons and neutrons in atoms	C2e
4. Explain how an atom can be radioactive	D13
5. Discuss the two types of chemical bonding, ionic and covalent	C2d
C. Identify the patterns in matter displayed in the periodic table	C5a
1. Distinguish atomic number and atomic mass number	
2. Define and distinguish atomic and molecular weight	C5e
3. Explain what isotopes are	
4. Label and explain chemical families	C5b
5. Discuss the relationship between electron structure and the periodic table	C5c
D. Organic chemistry	C5d
1. Identify the characteristic bonding patterns of carbon, hydrogen and oxygen	
2. Draw structural formulas of isomers given the molecular formula	
E. Elementary Stoichiometry	
1. Write and interpret simple chemical formulas	
2. Balance chemical equations	
III. Interactions of matter and energy	C1e
A. Define these dimensions in metric units and explain how the simpler dimensions are used to define the higher dimensions	
1. Length	D2
2. Area	
3. Volume	C1e
4. Mass	C1e
5. Time	D3
6. Velocity	
7. Acceleration	D3a, b
8. Force	D1a, b, c
9. Energy	D4
10. Power	D5a, b

Course Objective	Essential Skills Objective
B. Identify the mechanism of simple machines	C6a
1. Lever	
2. Pulley	
3. Inclined plane	
4. Wedge	
5. Screw	
C. Discuss the principles of simple machines	D8a, b
1. Conservation of energy	
2. Mechanical advantage	
3. Efficiency	
D. Identify devices to change each type of energy to as many other types as possible	C6d; D10i; D11a
1. Energy of movement	
a. Heat	
b. Kinetic	D6
2. Energy of position	D7
a. Electric	
b. Magnetic	
c. Gravitational	D7a
d. Chemical	D9
e. Nuclear	
3. Propagated energy	
a. Electromagnetic radiations	D10
E. Explain Newton's Three Laws of Motion	D6a, b
1. Inertia	D6b
2. F = ma	
3. Every action produces an opposite and equal reaction	
F. Use equations to make predictions about falling objects	
1. Distance traveled	
2. Time traveled	
3. Velocity	
4. Acceleration	
G. Discuss the measurements of molecular energy	
1. Heat	D14
a. Conduction	D14e
b. Convection	
c. Radiation	
2. Temperature	D14b, c
3. Explain the difference between heat and temperature	D14d
H. Light and sound waves	D11b; D12
1. Ways waves can interact with matter	
a. Transmission	
b. Absorption	
c. Refraction	
d. Diffraction	
e. Reflection	
2. Properties of waves	
a. Troughs	
b. Crests	
c. Wavelength	
d. Nodes	

Course Objective	Essential Skills Objective
e. Amplitude	
f. Frequency	
g. Constructive interference	
h. Destructive interference	
3. The electromagnetic spectrum	D10
a. Radio	D10j
b. Microwaves	H11h
c. Infrared	
d. Light	
e. Ultraviolet	
f. X-rays	
g. Gamma rays	
I. Electrostatics and electric circuits	
1. Discuss the imbalance that creates charged piece of macroscopic matter	D10a, b
2. Explain induction	
3. Explain what an electric current is	D10d; D10h
4. Describe the relationship between an electric current and its magnetic field	D10d, b
5. Distinguish between an insulator and a conductor	
6. Draw and label electric circuits	D10f
a. Wires	D10e
b. Resistors	
c. Batteries	
d. Switches	
e. Ground	
7. Identify the units used to measure electricity within a circuit	D10e
a. Volts	
b. Ohms	
c. Amperes	
d. Watts	

Key
I = Introduce
D = Develop
R = Reinforce

Essential Skills

Science (1981 Revision)

Topic	Concept/Skills	K-4	5-8	9-12
A. *Problem Solving*	The learner will use process skills (observing, classifying, inferring, predicting, measuring, communicating, interpreting data, making operational definitions, formulating questions and formulating models) as a basis for solving problems.	I D	D	D
B. *Process of Science*	The learner will			
1. Observing	a. make observations in a variety of ways using all of the senses.	I	D	D
	b. use indirect methods if direct sense experience is insufficient to observe objects or events.	I	D	D
	c. make quantitative observations to accumulate precise data.	I	D	D
2. Classifying	a. classify objects on the basis of observations.	I	D	D
	b. classify objects and events on observable similarities and differences of selected properties.	I	D	D
	c. use classification keys to place items within a scheme or to retrieve information from a scheme.		I	D
3. Inferring	a. make evaluation and judgment based on observations.	I	D	D
	b. make predictions based on observations of events.	I	D	D
4. Predicting	a. formulate an expected result based on past experience.	I	D	D
	b. confirm a prediction through an experiment.	I	D	D
5. Measuring	a. measure properties of objects or events by direct comparison through standardized units of measurement.	I	D	R
	b. interrelate identifiable characteristics which can be measured to provide quantitative values in the description of physical phenomena.	I	D	D

Topic		Concept/Skills	K-4	5-8	9-12
6. Communicating	a.	keep accurate records of observations for checking and rechecking by others.	I	D	D
	b.	make graphic representations of accumulated records of observations and communicating this information clearly and meaningfully.	I	D	D
7. Interpreting Data	a.	use processes such as classifying, predicting, inferring and communicating to interpret data.	I	D	D
	b.	revise interpretations of data based on new information or revised data.	I	D	D
8. Making Operational Definitions	a.	define observed phenomena to differentiate this information from other phenomena.	I	D	D
	b.	make precise definitions of objects or events based on observable characteristics of the phenomena and the operations performed as well as on mathematical relationships.	I	D	D
9. Formulating Questions and Hypotheses	a.	make questions on the basis of observations.	I	D	D
	b.	generate more questions or problems to be solved through application of other processes of science.	I	D	D
	c.	devise a statement which can be tested by experiment.	I	D	D
10. Experimenting	a.	design data - gathering procedures as well as testing a hypothesis.	I	D	D
	b.	identify variables and control aspects of an experiment.		I	D
	c.	consider limitations of methods and apparatus of experimentation.	I	D	D
11. Formulating Models	a.	devise models on the basis of acceptable hypothesis or hypotheses yet to be tested.		I	D
	b.	use models to describe and explain interrelationships of ideas.	I	D	D
C. *Matter*		The learner will			
1. Description	a.	describe the surfaces by color, shape and texture.	I D	R	R

Topic	Concept/Skills	K-4	5-8	9-12
	b. differentiate among solids, liquids, gasses.	I	D	R
	c. classify similar objects by particle size.	I	D	R
	d. explain the difference between mixtures and solutions.		I	D
	e. measure matter by both volume and mass.	I	D	R
	f. describe density as light or heavy.	I D		
	g. predict ability of objects to float in water.	I	D	
	h. define density as mass per unit volume.		I	D
	i. explain changes in matter (form or phase) requiring energy exchange (input or output).		I	D
2. Structure	a. explain structure of matter as array of atomic building blocks.		I	D
	b. describe crystal structure by shape.	I	D	R
	c. explain crystals.		I D	D
	d. classify matter according to theoretical structure, e.g., ionic or covalent (electrical attraction or electron sharing).			I D
	e. describe the theoretical chemical atom as dense positive nucleus surrounded by negative electron cloud.			I D
	f. differentiate between living and nonliving matter.	I	D	R
3. Earth-Space Relationships	a. describe earth as sphere in space, part of solar planetary system.	I	D	R
	b. describe the solar system in the context of its relative galactic position and the theoretical relations among celestial objects.		I	R
	c. recognize sun as principal source of earth energy.	I	D	R
	d. describe climatic zones of earth (polar, temperate, topic).	I	D	D
	e. recognize atomsphere, lithosphere, hydrosphere as gaseous, solid and liquid components of earth structure	I	D	R
	f. classify rocks by their methods of formulation (igneous, metamorphic, sedimentary).	I	D	R
	g. show familiarity with theoretical structures of lithosphere (plate tectonics, mantle, theoretical liquid core).		I	D

Topic	Concept/Skills	K-4	5-8	9-12
	h. test rock and stones for color, hardness, crystal structure.	I	I D	D
	i. differentiate fossiliferous stones from igenous or metamorphic.		I	I
	j. explain water cycle and related weather phenomenon.		I	D
	k. relate tilt of polar axis to seasonal variations.		I	D
	l. explain tidal behavior as earth-moon-sun gravitational coupling.		I D	R
	m. describe forces tending to change the earth's surface (water flow, air flow, vulcanism, humans).	I	I D	D
4. Water	a. show appreciation of water as unique substance essential to life functions and to many natural inorganic changes.	I	D	R
	b. describe molecular structure of water.		I	D
	c. explain theoretical weak polar electrical properties of water molecules.			I D
	d. explain aqueous solutions as molecular or ionic dissociation.		I D	D
	e. explain acid-base water solutions by measuring with appropriate indicators.	I	I D	D R
	f. explain the acidity/basicity of water solutions as functions of hydrogen ion concentration (pH).		I	D
5. Elements	a. differentiate among elements, compounds and mixtures.	I	D	R
	b. show awareness of periodicity of elements by using the periodic table.	I	D	R
	c. differentiate among metals, nonmetals and noble elements.		I	I D
	d. classify elements by electron configuration.			I D
	e. explain peculiar properties of oxygen, hydrogen and carbon and their roles in basic life processes.		I	D
	f. using the periodic table, show awareness of molecular weight and use Avagadro's number to explain mole concept.			I D
6. Technology	a. identify and use simple machines.	I	D	R
	b. predict force changes of direction and intensity using simple machines.		I D	R

Topic	Concept/Skills	K-4	5-8	9-12
	c. show systems for converting energy or transferring information, interpreting such systems as planned uses of peculiar properties of certain types of matter such as fuel, engines, electricity generation, light generation, radio, television, computers.		I	D
D. *Energy*	The learner will			
1. Force	a. identify any pushing or pulling on any object as a force.	I D	D R	R
	b. measure forces with balances, springs and other appropriate devices.	I	D	D R
	c. define energy qualitatively as cause for change.	I D	D	R
2. Distance	measure distance in appropriate standard or arbitrary units.	I	D	D R
3. Time	a. develop ability to tell time.	I D	R	R
	b. measure time intervals using standard clock stopwatch.	I	D	D R
4. Work	make mathematical comparisons of force, distance and time as an operational definition of power.		I	D
5. Power	a. make mathematical comparisons among force, distance and time as an operational definition of power.		I	D
	b. define energy quantitatively as a work equivalent (total work done equals energy consumed).			D
6. Kinetic energy	a. identify and define in operational setting the three Newtonian laws of motion.		I	D
	b. define inertia qualitatively as the resistance to change from outside force.		I	D
7. Potential energy	a. identify gravity as force (pull).	I	D	R
	b. measure gravitational attraction of earth (weight).	I	D	R
	c. identify gravitational attractions of celestial objects; establish		I	D
	d. calculate gravitational acceleration and quantify energy equivalents of mass times height.			I D

Topic	Concept/Skills	K-4	5-8	9-12
8. Energy conservation	a. identify examples of conservation of energy in mass-matter interchanges.		I	D
	b. define conservation as total energy of any system as being equivalent both before and after any change within that system.		I	D
9. Chemical energy	a. explain food, fuel energy in relation — (theoretical) to making and breaking bonds between atoms in compounds.			I D
	b. describe and identify foods as sources of biochemical energy.	I	D	R
	c. describe the operation of electrochemical battery (electric cell) as ionic potential of component substances		I	D
	d. describe the theoretical function of the electrolysis process		I	D
	e. use safety procedures in handling hazardous chemicals.	I	D	D
10. Electromagnetic energy	a. perform simple demonstrations of static electricity using paper, plastic, rubber.	I	D	
	b. identify electrical forces of both attraction and repulsion.		I	D
	c. recognize polarity of magnetic substances, predict attraction or repulsion with polar similarity or dissimilarity.	I	D	
	d. generate electrical energy with moving magnet and wire conductor.		I	D
	e. measure electric variables with appropriate instrumentation.		I	D
	f. perform simple demonstrations of interaction among batteries, bulbs and wires.	I	D	
	g. construct electrical circuits and predict performance of variables as function of circuit design.		I	D
	h. differentiate between direct and alternating current and predict energy transmission with each form of current.		I	I D
	i. describe electric power generating facilities as energy converrion devices, e.g., water potential, chemical potential, atomic potential into electric potential.		I	I D

Topic	Concept/Skills	K-4	5-8	9-12
	j. describe electromagnetic spectrum as theoretical mechanism for explanation of radio, light, x-ray and other waves.		I	D
11. Light energy	a. show light production as electrical or chemical energy conversion.	I	D	R
	b. explain light propagation as wave phenomenon.		I	D
	c. demonstrate light control through optical devices such as mirrors and lenses; predict effects of various optical structures.	I	D	D
	d. explain optical function of human eye, formulation of cameral image.	I	D	
	e. explain light propagation as particulate (photon) projection.			I
	f. identify colors.	I D	R	R
	g. differentiate between colors and pigments.		I	I D
	h. explain optical spectrum as small segment of electromagnetic spectrum.		I	D
12. Sound energy	a. describe sounds as low, high, quiet, loud, pleasant, harsh.	I	D	R
	b. explain sound as compression wave phenomenon.		I	D
	c. measure sound in terms of energy units.			I D
	d. relate conversion of several energy forms - electrical, mechanical - into sound.	I	D	R
	e. explain the function of several sound devices such as ear, telephone, vocal cords, loudspeaker.		I	D
13. Nuclear energy	a. describe atomic nuclear structure and explain instability theory.		I	D
	b. describe functioning of nuclear reaction, heat/electricity generator.		I	D
	c. recognize normal background radiation phenomenon.		I	D
	d. demonstrate appropriate safety precautions for dealing with radioactive materials.			I D
	e. differentiate nuclear radiation phenomenona (alpha, beta, gamma radiation).			I D
14. Heat energy	a. demonstrate heat as change agent (cooking, melting, reforming).	I	D	R
	b. measure temperature.	I	D	R
	c. explain temperature as molecular motion.		I	D

Topic	Concept/Skills	K-4	5-8	9-12
	d. differentiate between heat and temperature.	I	D	R
	e. explain heat transfer mechanisms convection, conduction, radiation).	I	D	R
	f. demonstrate heat generation and loss in mechanical energy exchanges.		I	D R
E. *Interaction*	The learner will			
1. Interdependence	a. identify evidence of interdependence in living systems.	I D	D R	R
	b. identify evidence of interdependence within organisms	I	D	R
	c. draw inferences about interdependence based on field observations.		I D	D R
	d. describe plant/plant, plant/animal animal/animal interactions.	I	D R	R
	e. describe biogeochemical cycles.	I	D R	D R
2. Heredity	a. describe organic systems from simple to complex.	I	D	D R
	b. identify and describe function of cellular parts.		I D	D
	c. compare cellular models in all living things.		I D	D
	d. describe structure and function of elemental cellular particles such as DNA and RNA.		I D	D
	e. explain the transfer of genetic information.		I	I D
	f. explain the mechanism of genetic analysis such as gene pools, statistical application, recombinant alternatives.		I	I D
	g. explain heredity as the mode of species continuation.		I	D
3. Environment	a. describe a comprehensive model of environmental interaction.	I	I D	R
	b. construct models for analysis of environmental problems.		I D	D R
	c. recognize environmental impact on his or her personal life.	I	D	R
	d. manage his or her personal environment in an effective manner.	I	I D	D R
	e. analyze systems in the environment in order to understand the holistic model.		I D	D R
4. Change	a. describe the changes as a necessity for species survival.	I	D R	R
	b. Identify examples of change in macrosytems, among organ systems, organisms and ecological systems.	I D	D R	R

Topic	Concept/Skills	K-4	5-8	9-12
	c. interpret change and equilibrium as a dynamic interaction.		I	D R
	d. measure and analyze changes in living systems.	I D R	D R	R
5. Equilibrium	a. recognize and describe systems in equilibrium.		I	D R
	b. define equilibrium in living systems.		I D	R
	c. defend the concept of equilibrium by using models.		I	D R
	d. measure equilibrium.		I D	R
6. Organisms	a. describe simple-complex organisms on an evolutionary continuum.		I D	R
	b. identify and describe complex body systems (plant, animal and protists).		I D R	R
	c. relate function to structure of body systems (plant, animal and protists).	I	D	R
	d. apply measurement skills to analysis of systems.	I	I D	R

Field Trips

Science field trips traditionally have been planned and executed by those few science teachers brave enough to overcome local policy restrictions, transportation hassles and financial roadblocks. Students have rarely exhibited lack of enthusiasm for learning during the on-site visit of potentially interesting places such as industrial plants, hospitals, museums and the like. Many teachers have felt such divided loyalties to administration and to students that perhaps all the work involved in planning and taking a field trip has not been worth the effort. A closer look at the educational value of field trips might expand our horizons in terms of attitudes toward and different approaches to planning science field trips.

One can consider the added value of field trips as career education. Career education encompasses the total education of the student, including the intellectual and personal growth, as well as the development of vocational interests and skills.

How do science field trips fit into basic education?

Most field trips deal with providing students with cognitive experiences with science subject matter at the grade level/or in the science area involved. There are other cognitive experiences and even some affective ones which should also be considered important and should be included in the plans for any field trip. Some of these experiences might result in the trip being considerably more meaningful for many of the students.

Science field trips can also contribute to the personal growth of the student. They provide an opportunity for him to observe and relate, first-hand, to a variety of people working scientific or science related careers. Other opportunities include seeing people involved in continued learning, working together, solving problems and carrying out varying levels of responsibility. Probably most important value for field trips is the personal growth which can result from students, teachers, parents and others being together away from the school environment in an atmosphere of cooperative teaching, learning and fellowship.

Educators at all levels need to be made aware of the immediate need for experiences outside the school environment to provide a comprehensive education for all students. With this awareness will come increased support for such experiences so that they might become an integral part of the instructional program.

The maximum potential of field trip sites should be recognized. Many places offer a variety of science-related occupations at various levels for differing numbers of students to investigate. For example, students visiting a hospital can observe and interview people as physicians, nurses, nurses aides, pharmacists, medical secretaries, dietitians, researchers, laboratory and X-ray technicians, physical and respiratory therapists, volunteer workers, etc. Some field trips might involve only a small number of students. It is essential that the group not be too large to accomplish the stated objectives of the trip. Suggestions for science field trips which can include experiences in the learning of science content and processes as well as career and general interest information follow.

— Science Center and Museum
— Community Health Center
— Industrial Plant
— Radio and TV Station
— Zoo
— Fish Hatchery
— Doctor/Dentist
— Engineering Firm
— Electronics Repair Shop
— Lumber Company
— Science Equipment Sales Co.
— Mortuary
— Rocket and Space Center
— Hospital
— Community Service Agency
— Farm
— Airport
— Crime Laboratory
— Animal Hospital
— Greenhouse/Florist
— Photography Studio

- Dry Cleaner
- University (science teaching and research)
- Pharmacy
- Geological Sites

Participating students should be involved in the planning of the field trip and should be encouraged to look for the variety of occupations and types of people at the field trip site, in addition to the main science content objective of the field trip. Students might draw up their own observation/interview sheet to take along on the trip to record the information about the occupation(s) in which they have an interest.

Some provision should be made for follow-up activities, preferably creative ones which are meaningful to the students. The techniques listed below can provide ways of relating science field trips to the students' general science knowledge, hobbies and citizen and consumer responsibilities as well as to their future jobs.

- Students can participate in role-playing and simulation activities, panel discussions and debates.
- Students can write summaries, want ads, news releases, stories, songs and plays.
- The student may also do the following activities.
  - Make an oral report
  - Read a book or article
  - Compile a notebook
  - Construct a bulletin board
  - Make a collection of related materials
  - Draw a chart
  - Construct a diorama
  - Draw a mural
  - Draw a cartoon strip
  - Produce a filmstrip
  - Produce a puppet show
  - Adapt a game ("20 Questions", "What's My Line?", "You Are There", "To Tell the Truth", "Jeopardy")
  - Go on related trips, have resource people in or conduct interviews

Making necessary arrangements, careful planning and follow-up activities are essential ingredients for any science field trip. A sample evaluation checklist follows.

References

Dickson, Helen K., Career Explorations. ***Design for Field Trips,*** Washington: Department of HEW, Office of Education, 1971. ED 69919

Dummer, Richard, ***Field Trip Exploration for Junior High,*** White Dear Lake Independent School District 624, Minn., 1973. ED 107760.

Dickson, Peter, "Confessions of a Field Trip Addict," ***Learning,*** November, 1974, 80-84. ED 069919

Miller, Joseph A., "Career Education Field Trips," ***Man/Society/Technology,*** Volume 34, No. 4, January, 1975, 118-19. ED 069919

Thrist, Don, "Field Trips—A Priceless Ingredient," ***Journal of Geological Education,*** Volume 23, 1975.

Science Field Trip Evaluation Checklist

Arrangements

____________ Adequate pretrip arrangements were made with the school administration, other teachers and parents.

____________ Transportation arrangements were adequate.

____________ Necessary provisions for meals, overnight accommodations, etc. were made.

____________ Plans were made for special needs (medical, physical) for certain students.

____________ Adequate supervision was provided.

____________ A list of all student's home phone numbers was compiled for the trip.

____________ Necessary arrangements were made for those students for whom financial problems might interfere with their participation on the trip.

Planning

____________ The trip was planned well enough in advance to schedule the kinds of activities desired for the group.

____________ The trip was planned to supplement regular classroom science instruction.

____________ Students were involved in the planning and objectives.

____________ Students were given enough prior information to explain the purposes of the trip.

____________ Students had choice of participating or not participating in the field trip.

____________ Students were given guidelines to follow and specific tasks to accomplish during the trip.

____________ The group was small enough to accomplish the objectives of the field trip.

____________ People with whom the students would have contact were informed about the students and the kinds of information in which they were interested.

Follow up

____________ Provisions were made for posttrip sharing experiences.

____________ Thank you letters were sent to the host personnel.

____________ Notes were made on problems encountered for changes in future trips or recommendations were made that future trips be eliminated.

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